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**NANTICOKE  
ENVIRONMENTAL MANAGEMENT  
PROGRAM**

**HISTORICAL TRENDS  
AND INDUSTRIAL AIR  
QUALITY IMPACT  
IN THE  
HALDIMAND-NORFOLK REGION**

**REPORT NO. ARB-004-85-ARSP**

**JANUARY, 1985**

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Ontario

**Ministry  
of the  
Environment**

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## 1.0 Introduction

The Nanticoke industrial complex comprised of a thermal generating station (TGS), a steel making facility and an oil refinery is situated on the northern shore of Lake Erie in the Haldimand-Norfolk region of southern Ontario. The Ontario Hydro Generating Station initially started operations in 1973 and was capable of full operation (4000 MW) by 1978. However, to date, it has been operating at a capacity factor of about 50%. The oil refinery has been operating at near capacity (100,000 bbl/day) since January 1979 except for some scheduled shutdowns; while the steel plant began limited operations in the summer of 1980 and by 1982 was producing over one million tons of steel per year.

The Nanticoke TGS is the major emitter of sulfur dioxide ( $\text{SO}_2$ ) and nitrogen oxides ( $\text{NO}_x$ ) in the Haldimand-Norfolk region (see Section 2.2). Total suspended particulate (TSP) emissions arise from coal handling and ash operations at Ontario Hydro and Stelco and contribute to the dustfall loadings relatively close to these plants. Other pollutants directly emitted by the Nanticoke operations - mainly Stelco and Texaco - are hydrocarbons including polynuclear aromatic hydrocarbons, hydrogen sulfide, carbon monoxide, and fluorides. In addition to these primary emissions, there exist secondary pollutants such as ozone ( $\text{O}_3$ ), generated from primary pollutants by atmospheric chemical reactions under certain meteorological conditions.

Of all the contaminants measured in the Haldimand-Norfolk region of southern Ontario, only three, ozone, TSP and  $\text{SO}_2$  have exceeded their respective air quality criterion. Since  $\text{O}_3$  is the topic of a separate report (MOE Report ARB-005-85-ARSP), the analysis presented here is primarily directed to TSP and  $\text{SO}_2$ . It should also be noted that TSP data (13 - 14 monitors sampling over four years) and  $\text{SO}_2$  data (approximately 20 monitors sampling over eight years) provided sufficient measurements for historical trend analyses.

The first part of this report displays the air quality monitoring results and updates the previous climatological and aerometric analyses (MOE Report ARB-18-82-ARSP) to the end of 1982. The second part of the report examines historical trends and industrial air quality impact.

## 2.0 Presentation of Historical Air Quality Data

Air Quality and meteorological monitoring has been carried out since the fall of 1978 under the auspices of the Nanticoke Environmental Management Program (NEMP), a joint venture involving the local industries, Environment Canada and the Ontario Ministry of the Environment. In addition to the NEMP network, Ontario Hydro has been operating an SO<sub>2</sub> network of approximately 16 monitors since 1975 and the MOE West Central Region has been operating gaseous monitors at Cheapside and Simcoe as well as a hi-vol network consisting of 6 samplers. The data set analysed here, consists of NEMP network data - (January 1979 to December 1982), MOE West Central Region data - (January 1979 to December 1982) and Ontario Hydro network data - (January 1975 to December 1982). Monitoring locations for all stations in the Nanticoke area are shown in Figure 1 and a description of the parameters measured at each station appears in Table 1.

In order to calculate an annual mean which is meaningful, only those stations reporting at least 75% of the maximum possible hourly observations have been used for trend analysis and for comparison with the annual criterion. All stations have been included for comparison with the hourly or daily criterion.

### 2.1 Ambient Air Quality Criteria (AQC)

Table 2 lists the current Ontario criteria for desirable ambient air quality for four pollutants which are discussed in this report. As yet no criteria have been established for non methane hydrocarbons (NMHC) and methane (CH<sub>4</sub>). For total reduced sulfur (TRS) there is no general criteria available. Ontario AQC are based upon the examination of all known effects of the contaminant and are, in terms of time-concentration values, below a concentration known to have significant adverse effects on man, animals, vegetation or property. It should be noted here that carbon monoxide (CO) has not been included in the list of parameters because in the Haldimand-Norfolk region the CO concentrations have been extremely small, (< 2 ppm - 95% of the time).

### 2.2 Annual Emissions

Annual emissions for SO<sub>2</sub> (1975 to 1982), particulates (1979 to 1982) and NO (1979 to 1982) are shown for each industry in Figures 2 to 4 respectively. Of the total SO<sub>2</sub> emissions, Ontario Hydro emits approximately 94%, Texaco about 4% and Stelco 2% (based on 1981 and 1982 data). For particulates and NO emissions in

the Nanticoke area, once again, Ontario Hydro is the major emitter. Based on the most recent data available (1982), Ontario Hydro, Texaco and Stelco emitted approximately 75, 15 and 10% of the particulate emissions respectively and 92, 5 and 3% of the NO emissions respectively.

### 2.3 Overall Network Statistics - Box Plots

Concentration trends for each of the following seven pollutants - SO<sub>2</sub>, TSP, O<sub>3</sub>, NO<sub>2</sub>, TRS, NMHC and CH<sub>4</sub> - are displayed by means of a box plot technique in Figures 5 to 11. The box plots are based upon the distribution of all measurements made in the network. For each pollutant, the mean, median, maximum, 10, 25, 75 and 90 percentiles are plotted annually.

### 2.4 Sulfur Dioxide Data

Annual averaged SO<sub>2</sub> concentrations by station for an eight year period (1975-1982) are shown in Figure 12. Annual averaged concentrations were less than half of the annual SO<sub>2</sub> criterion (20 ppb).

Network hourly averaged SO<sub>2</sub> exceedances by year are shown in Figure 13. There have been 111 known exceedances of the hourly AQC (250 ppb) throughout the 8 year period. The maximum number of hourly exceedances occurred in 1976 (20) and 1978 (20). 1980 had the fewest number of exceedances (8).

Seasonally<sup>1</sup>, SO<sub>2</sub> exceedances were most frequent during the summer period (52) and least frequent during winter (11), Figure 14. For a detailed discussion of the SO<sub>2</sub> exceedance events, refer to MOE Report number ARB-169-84-ARSP entitled 'Nanticoke Environmental Management Program Analysis of SO<sub>2</sub> Exceedance Events in the Haldimand-Norfolk Region for 1975 to 1983', where it was concluded that Ontario Hydro is the major source of the one-hour AQC exceedances.

### 2.5 Total Suspended Particulates Data

Annual averaged TSP concentrations by station for a four year period (1979 to 1982) are shown in Figure 15. Annual averaged concentrations range from 35 to 50 ug/m<sup>3</sup>. These values are below the annual AQC of 60 ug/m<sup>3</sup>. Network

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1. Winter = December-February; Spring = March-May; Summer = June-August; Fall = September-November.



exceedances of the daily AQC ( $120 \text{ ug/m}^3$ ) for each year are shown in Figure 16. At first glance it appears that 1979 was a bad year for particulates with 19 recorded exceedances. It should be noted however, that during 1979 and 1980 the high-volume sampler at Long Point (SW37) recorded 13 exceedances. These high values at Long Point were attributed to its location (on a sandy beach) where windblown dust is a considerable problem. The monitor was relocated at SW40 in early 1981. During the period of study the average number of TSP exceedances per year for the network is 11. However, this value becomes 7 if the exceedances at Long Point are omitted. An analysis of these exceedances will be the subject of a separate NEMP report.

## 2.6 Meteorological Data

Local wind flow patterns and mixed layer heights are important controlling factors in the dispersal and transport of pollutants in the Haldimand-Norfolk region. A meteorological tower located near Jarvis provides wind measurements at 10, 32, and 85 m levels while an acoustic sounder located at NNE07 provides data on mixed layer heights up to 1000 m.

The distribution of winds (hourly averaged) at the 10 and 85 m level annually and seasonally for the period 1975 to 1982 is shown in the wind rose plots, Figures 17 and 18 (For a detailed discussion of the wind patterns in the Haldimand-Norfolk region see MOE Report No. ARB-18-82-ARSP). Briefly, a strong westerly wind component is observed during the winter period and a strong southerly wind flow during the summer. High wind speeds during the spring, summer and fall season are associated with southerly wind flows and during winter with westerly flows.

The diurnal pattern of mixed layer heights annually and seasonally for onshore and offshore winds is shown in Figures 19 and 20. Of particular interest is the rapid growth rate of the mixed layer during the summer and fall season. At this time of the year, rapid heating of the surface layer during the morning hours coincides with the rapid growth rate of the mixed layer. During the winter and spring, there is little variation in the diurnal pattern of mixed layer heights.

## 2.7 Aerometric Analysis of Gaseous Compounds

This section of the report complements the earlier aerometric analysis (see Report No. ARB-18-82-ARSP) and updates the concentration plots to the end of 1982. Once again, hourly average concentrations as a function of wind direction

for four gases - SO<sub>2</sub>, O<sub>3</sub>, TRS and NO<sub>2</sub> - have been plotted annually, seasonally and according to the number of exceedances of MOE's air quality criteria, for each station in the Haldimand-Norfolk region (Figures 21 to 37). Results substantiate previous findings in that elevated SO<sub>2</sub> concentrations correlate well with southerly wind flow patterns suggesting that Ontario Hydro is the major contributor to high short-term SO<sub>2</sub> concentrations while sources south of the lake influence background levels. For O<sub>3</sub>, elevated concentrations at SW37 during southerly winds suggest the source of the pollutant to be south of the border. For NO<sub>2</sub>, directional distribution at NNE39 coincides with close proximity of the industrial centre of Hamilton and finally, elevated TRS at WNW03 for southwesterly winds suggests Stelco as the source while elevated TRS at NNE05 during west-southwesterly flow indicates Texaco as the source.

## 2.8 Spatial Distribution of SO<sub>2</sub> and TSP

The spatial distribution of the long term averages for SO<sub>2</sub> (8 years) and TSP (4 years) is shown in Figures 38 and 39 respectively. For SO<sub>2</sub>, the network shows two areas of maximum long-term average (6 ppb); one area is approximately 10 km north-northeast of Ontario Hydro and the other about 40 km to the north-northeast. For TSP, stations closest to the industry did not show the maximum long term average. Particulate levels in the Haldimand-Norfolk region are most probably related to agriculture rather than industrial activity, since this region is primarily an agricultural area.

## 3.0 Statistical Analysis of Historical Trends and Industrial Air Quality Impact

This investigation of historical trends and industrial impact in the Haldimand-Norfolk region of Southern Ontario attempted to use the existing database to make statistical statements about overall changes in air quality over time and average industrial impacts. Although this database is extensive in time and range of measurements, the network was not originally designed to generate data for sophisticated statistical analyses. Consequently, few of the inter-relationships between meteorological (meso and micro) effects and airborne pollutant levels which undoubtedly exist could be examined. The need to 'balance out' all other possible influential factors when analysing for a particular factor of interest meant that effects (even frequently) observed may not have been found in a statistical analysis. In such cases, the circumstances associated with the occurrence of this effect may have coincided too often with other influential industrial, meteorological or seasonal effects.

The need to use only the most robust and distribution-free statistical techniques (see Conover 1980) meant that more interpretive and sophisticated modelling was generally inappropriate although it was attempted in some instances.

The data base used in this statistical analysis comprised eight years (1975-1982) of hourly values for the following parameters: SO<sub>2</sub> concentrations from approximately twenty stations; wind speed and wind direction (85 m level of Jarvis met. tower); air temperature (10 m level of Jarvis met. tower); Nanticoke TGS station load and corresponding SO<sub>2</sub> emissions and finally, four years (1979-1982) of daily TSP concentrations from approximately fourteen stations.

Section 3.1 examines the annual and seasonal distribution of TSP as well as the local industrial impact on TSP levels in the Haldimand-Norfolk region. Sections 3.2 and 3.3 look at the annual variation in network daily average SO<sub>2</sub> and network daily maximum SO<sub>2</sub>, while Section 3.4 describes the attempts that were made to separate some of the individual source contributions to ambient SO<sub>2</sub> levels in the Haldimand-Norfolk region.

### 3.1 Annual and Seasonal Distribution of TSP Throughout the Network

An investigation was made into the annual and seasonal distribution of TSP values for the period 1979-1982 inclusive. In order to delineate local TSP impact, comparisons were made between annual and seasonal TSP values for close-in monitors (NNW06, NW03, W07, and NNE05) and the remaining monitors in the network (9 or 10, depending on the year). Figure 40 shows the frequency distribution of TSP values for the close-in group of monitors and that of the remaining group for all seasons combined.

Figure 41 shows the winter TSP frequency distribution for the close-in group and all other monitors. In addition, the seasonal frequency distributions for the close-in and "other" samples were generated for spring, summer, and fall but are not shown because the relationship between the two groups appears to be the same in all seasons.

The seasonal frequency distributions of TSP values for the close-in monitors were found to be not significantly different from those of the remaining monitors by a chi-square test. Similarly, the annual and seasonal distribution of the geometric means of the close-in monitors were found to be not significantly different from the geometric mean of the remaining monitors.

Figures 42 and 43 show the winter frequency distributions of the network daily maximum and mean TSP values respectively. The frequency distribution for the close-in group is superimposed in each figure on the frequency distribution of the remaining samplers. As can be seen from the figures, the frequency distributions of the means of the two groups differ very little. These differences were found to be not significant by chi-square tests.

The difference between the frequency distribution of the group maximum for the two groups (for each season) was not tested statistically because the differing group sizes renders such a direct comparison inappropriate. However, the appearance of the histogram (for example Figure 42) is consistent with the hypothesis that monitors in the two groups have very similar maximum values. Industrial impact was not detectable by this test.

An impact study was also performed using TSP values from the close-in monitors downwind of the Stelco plant and upwind background monitor values. Impact occasions were selected for comparison if 2/3 of the hourly wind directions (during the twenty-four hour sampling period) remained within  $\pm 10^\circ$  of the approximate impact direction (see Figure 44). However, no statistical tests could be performed because an insufficient number of sampling periods were available.

In summary, industrial impact on TSP levels in the Haldimand-Norfolk region was not detectable by these tests.

### 3.2 Annual Variation in Network Daily Average SO<sub>2</sub>

An investigation was made into the seasonal variation of 'high' daily average SO<sub>2</sub> values (90th percentile of all days in appropriate season) with respect to time in order to detect the presence of any trends in the frequency of occurrence of high daily values. The 90th percentile for winter, spring, summer, and fall were 20, 10, 7, and 10 ppb respectively.

Figure 45a shows the daily network average SO<sub>2</sub> concentrations for 1975 with Nanticoke TGS daily average SO<sub>2</sub> emissions superimposed. The approximate 90th percentiles are shown, from which it can be seen that exceedances of these levels are infrequent and quasi-independent events and as such they can be used as an index for detecting trends in average SO<sub>2</sub> levels (Lindgren). Figures 46a to 52a show the average network SO<sub>2</sub> data for the years 1976 through 1982.

Figures 45b to 52b show the Nanticoke TGS average daily load and average air temperature while Figures 45c to 52c show the daily network maximum SO<sub>2</sub> level and Nanticoke TGS SO<sub>2</sub> emission at the maximum concentration hour. By comparing the relative frequencies of 'high' average SO<sub>2</sub> values in different years (for each season) the hypothesis that, there is a trend in the average SO<sub>2</sub> levels can be tested. These relative frequencies are plotted for each season in Figures 53 to 56. Spearman's Rho tests of these relative frequencies (or proportions) showed that there was no significant trend over time in average daily network SO<sub>2</sub> levels.

Investigation was also made into the seasonal variation of 'high' daily average SO<sub>2</sub> values (90th percentile) with respect to the average daily amount of coal used by Hydro and the average percentage of sulfur in the coal. Figures 53 to 56 also show the annual variation in the percentage of high daily average SO<sub>2</sub> values (for each season) and the corresponding levels of average coal consumption and percentage of sulfur in the coal. Statistical tests of association (Spearman's Rho) were performed between the percentage of high daily average SO<sub>2</sub> levels (above the 90th percentile) and each of the parameters, coal consumption (C) and percentage of sulfur, (P) for each season. A negative correlation between the amount of coal used (C) in summer and the relative frequency of 'high' daily network averages was confirmed by the Spearman test (test statistic of -1.375 with 5% critical value of -0.619), i.e. greater coal use did not result in higher daily SO<sub>2</sub> readings.

In order to investigate a possible plume height effect in summer the association between the frequency of high network averages and the coal use statistic (P-C) was tested. Large values of P-C indicate occasions where Nanticoke TGS used relatively less coal but increased (relatively) the percentage of sulfur.

A Spearman's test of (P-C) against frequency of high network averages was significant (test statistic of 0.714 with 5% critical value of 0.619). This is depicted in Figure 57 where for each year the coal used and proportion of sulfur are plotted against the corresponding proportion of days in that year having high network daily maxima.



An interpretation of this result would be that decreases in coal usage and corresponding increases in the percentage of sulfur in the coal are associated with a higher frequency of high daily network SO<sub>2</sub> averages. This is suggestive of a plume height effect in addition to the rate of emission of SO<sub>2</sub>.

### 3.3 Annual Variation in Network Daily Maximum SO<sub>2</sub>

Investigation was made into the yearly variation in the percentage of daily maximum SO<sub>2</sub> values ( $\geq 120$  ppb) in each season with respect to variable load and meteorological parameter values. A cutoff point of 120 ppb was chosen because events coinciding with high (above 120 ppb) SO<sub>2</sub> were relatively independent (in time) from those with low (below 120 ppb) SO<sub>2</sub>. (See Barker and McMillan 1983). Parameters examined were Nanticoke TGS load, SO<sub>2</sub> emissions, percentage of sulfur in coal, wind speed, wind direction and air temperature. Days selected for further analysis were those whose wind direction around the time of the maximum SO<sub>2</sub> level was persistent (for at least 2 hr) from the statistically significant sector according to the time of year. These sectors were identified by constructing wind impact roses for each season depicting the relative frequencies of high daily maxima by wind direction as shown in Figure 58. The contingency tables shown, were then used to test the significance of specific wind direction sectors. Ninety percent of the days in each season with high daily maximum SO<sub>2</sub> values correspond to wind directions from the significant wind sectors.

Figures 59 to 62 inclusive, show the yearly variations in the percentage of days in each season with daily maxima over 120 ppb, together with the average values of the previously mentioned load and meteorological parameters.

Statistical tests of association (Spearman's Rho) between the percentage of network daily maxima which were high and each of the parameters was made for each season. For summer, fall, and winter none of the parameters considered was significantly associated with the frequency of high daily network maximum SO<sub>2</sub>. For spring, wind speed was found to be associated with the frequency of high daily network maximum SO<sub>2</sub> levels. The test statistic was  $-.6786$  which is exactly equal to the 5% critical value. The correlation is negative, hence, lower wind speeds are correlated with higher network maxima. This situation is depicted in Figure 63, where the wind speeds (scaled) are plotted against the corresponding proportion of days with high maxima.

Correlation tests (Spearman's Rho) were performed between various combinations of the above parameters and the frequency of high daily network SO<sub>2</sub> maxima. A combination of factors which appears to be significantly associated with high network daily maximum SO<sub>2</sub> values in winter was found. This was found by testing the association between the frequency of high network maxima in winter and the relative magnitude of the (scaled) values of percentage of sulfur (P), SO<sub>2</sub> emissions (E) and Load (L). From Figure 64 it can be seen that where  $P > E > L$ , high network maxima occur more frequently than when this ordering does not hold (e.g.  $P < E < L$ ).

If emissions are interpreted as a product of coal used and percentage of sulfur, and load as a linear function of coal used, this suggests that relative reductions in coal usage and increases in sulfur percentages result in more frequent high maxima for the winter season.

### 3.4 Impact of Ontario Hydro and Texaco on SO<sub>2</sub> Levels

In an attempt to obtain statistically significant estimates of the relative magnitude of the average SO<sub>2</sub> contribution by Texaco and Ontario Hydro in the Haldimand-Norfolk region, downwind impact analyses were undertaken using individual close-in monitors. Sectors to show Stelco's SO<sub>2</sub> impact in the Haldimand-Norfolk region were not studied because of the small number of days which are available for such an analysis and because the average Stelco SO<sub>2</sub> emissions are relatively small in comparison with those of Ontario Hydro and Texaco. Wind directions chosen for further study were those that put an impact monitor directly downwind of the Texaco refinery. This gave rise to five directions, one for each of the following impact monitor locations, NNE05, WNW03, NNW08, N07 and E05 (see Figure 65). To allow for the background SO<sub>2</sub> for each event analysis, background monitors were chosen such that they were upwind of the Texaco refinery. Impact occasions were found for which the wind remained in the appropriate impact direction ( $\pm 10^\circ$ ) for a minimum of four consecutive hourly observations. The average SO<sub>2</sub> concentration was then calculated for the impacted monitor and the background monitor (omitting the first and last observation to allow for time lags). Corresponding average values of air temperature, wind speed, Nanticoke TGS load and SO<sub>2</sub> emissions for the same time period were calculated.

A regression approach to modelling the (upwind-downwind) SO<sub>2</sub> amount in terms of station load, emissions, air temperature and wind speed for each season was attempted but did not yield an adequate fit to the data. This would have provided a possible means for separating the Hydro contribution of SO<sub>2</sub>.

Further work was conducted to statistically test the difference between 'similar' impact situations which occurred during pre- and post-operation of the Texaco refinery. 'Similar' situations are those which have Nanticoke TGS load values, SO<sub>2</sub> emissions, wind speed and air temperatures within 20% of each other. The validity of conditioning a test on such similarities was established by comparing 'similar' days during pre-Texaco operations with each other and likewise, similar days during post-Texaco operations.

The SO<sub>2</sub> monitor which had observations over the entire time period of interest and which also had the most consistent readings (in terms of relative size of downwind and upwind readings) was NO7. The chosen background upwind monitors for NO7 were W13 and WNW03 (see Figure 65).

The data for NO 7 - W13 consisted of 326 cases which were classified by wind speed (8 categories), Nanticoke TGS load (9 categories), SO<sub>2</sub> emissions (9 categories) and air temperature (9 categories). Taking similar days to be those with the same categories for wind speed, load, emissions and air temperature, there were 194 similarity classes, 34 of which contained more than one day. Of these, 22 had observations both before and after Texaco commenced operation. In these groups, the before and after mean SO<sub>2</sub> values were compared, and in fourteen the mean was higher for the cases covering the period of pre-Texaco operation. The hypothesis that there was no difference between average SO<sub>2</sub> during pre- and post-operations at Texaco was tested by applying a sign test, (See Conover 1980). This hypothesis was accepted since the probability of getting the observed number or a greater number, of positive differences was = .15. Hence no average impact was detected by this analysis.

A test was also conducted using NNE05 data to establish whether average SO<sub>2</sub> levels at NNE05 were higher on days specified by Texaco as having increased SO<sub>2</sub> emissions. The days spanned 1978-1982 and all seasons. Two hundred and thirty-seven higher emissions days were identified from the data set of 700 days. The average SO<sub>2</sub> values for each day were ranked within each season of each year. Similarly, the maximum values were ranked.



Mann-Whitney tests (Conover, 1980) were performed to determine whether higher average SO<sub>2</sub> values and higher maxima were associated with Texaco higher emission days within each season and year. No significant differences were found for average and maximum SO<sub>2</sub> levels between higher SO<sub>2</sub> emission days at Texaco and other days in the same season. Of course, this may be due in part to the fact that emissions described as higher than normal by Texaco are not uniformly high values. If there are a number of days with emissions only slightly higher than normal included in the special dates, this would definitely influence the statistical result. The actual volume of emissions on these days is not known to Texaco and hence was not available for this study.

#### 4.0 Summary

Air quality and meteorological data collected by the NEMP, MOE and Ontario Hydro monitoring networks in the Haldimand-Norfolk region of southern Ontario during the period 1975 to 1982 was presented and statistically analysed in this report.

Violations of the AQC for SO<sub>2</sub> (8 years) and TSP (4 years) have been very few. Less than .1% of the total number of SO<sub>2</sub> monitoring hours and less than 1% of the total number of daily TSP samples, exceeded their respective criteria.

The predominant wind direction in the Haldimand-Norfolk region (1975 to 1982) is from the SSW to W in fall, SSW to NW in spring, SSW to SW in summer and W in winter. Mixed layer heights show a rapid growth rate during the summer and fall. During the winter and spring there is little variation in the rate of growth of the mixed layer height.

Concentration roses were updated to the end of 1982. Findings were similar to those of 1979 in that elevated SO<sub>2</sub> correlates well with southerly winds implicating Ontario Hydro combined with sources south of the lake as the probable cause. Elevated O<sub>3</sub> at Long Point during southerly flows suggests the source of the pollutant to be south of the lake. The NO<sub>2</sub> directional distribution coincides with the close proximity of Hamilton, and finally elevated TRS has been attributed to Stelco or Texaco on occasion.

Trend analysis and industrial impact analysis revealed several interesting findings. For TSP, close-in monitors (NNW06, NW03, W07, and NNE05)

appear to show the same typical levels for all seasons as the remaining more distant (from industry) monitors. For SO<sub>2</sub> there were no significant time trends in network daily mean and maximum levels for any season. In summer, the relative frequency of network daily mean levels of SO<sub>2</sub> greater than 7 ppb was positively correlated with Nanticoke T.G.S. mode of coal usage, that is, its SO<sub>2</sub> emission rate in terms of coal amount and sulfur content was suggestive of a plume height effect. In winter, an analogous result holds for the relative frequency of network daily maximum levels of SO<sub>2</sub> greater than 120 ppb. This is positively correlated with the relative amounts of coal used and its sulfur content. Relative reductions in coal usage and increases in sulfur content results in more frequent high maxima. For individual industrial SO<sub>2</sub> impact, a directional, seasonal (before/after) impact study of Texaco's SO<sub>2</sub> contribution found no significant average impact. A study of special dates denoted as anticipated higher-than-normal SO<sub>2</sub> emission periods by Texaco also detected no significant average impact.

In summary - all analyses contained in this report indicate that the industrial impact on air quality in the study area is small. Nevertheless it should be kept in mind that over the eight-year study period, there were 111 recorded exceedances of the hourly SO<sub>2</sub> criterion, most of them attributable to local industrial activity. These exceedances have been studied in a separate report (ARB-169-84-ARSP) and the meteorological factors and emission sources responsible for them have been discussed in detail there.

## REFERENCES

1. Barker, T. J., McMillan, A. C. (1983): "Statistical Identification and Interpretation of Meteorological Scenarios for Local High SO<sub>2</sub> levels". "Proceedings 8th Conference on Probability and Statistics in Atmospheric Sciences". Hot Springs, Arkansas, November 1983. Amer. Met. Society.
2. Conover, W. J. (1980) "Practical Nonparametric Statistics", J. Wiley and Sons, New York.
3. Kiely, P. and Sahota, H. 1981: "Climatological and Aerometric Analysis on Nanticoke Environmental Management Program Data up to December 1979". MOE Report No. ARB-18-82-ARSP.
4. Kiely, P. and Sahota, H. 1984: "Nanticoke Environmental Management Program Analysis of SO<sub>2</sub> Exceedance Events in the Haldimand-Norfolk Region for 1975-1983". MOE Report No. ARB-169-84-ARSP.
5. Kiely, P. 1985: "Nanticoke Environmental Management Program Analysis of O<sub>3</sub> Exceedance Episodes in the Haldimand-Norfolk Region for 1979-1983". MOE Report No. ARB-005-85-ARSP.
6. Lindgren, G (1974): "Spectral Moment Estimation by Means of Level Crossings". Biometrika: Volume 61, part 3.
7. Sahota, H., Kiely, P., and Lusi, M. A. "Air Quality Impact of the Nanticoke Industrial Development". Presented at the 3rd International Conference on Environmental Pollution, Niagara Falls, October, 1982.

PK:jjh

6AR14-1

Table 1  
Station Location and Description

Geog. Id	Numer. Id	Site Name	SO2	O3	NOX	CO	TRS	HC	TSP	COMP HI-VOL	COH	PREC
NO7	22906	Sandusk	X		X							
N15	22812	Garnet	X									
N17	22951	Hagersville South							X	X		
NNE05	22904	Walpole South School	X				X	X	X	X		
NNE09	22822	Dry Creek	X									
NNE10	22903	Cheapside	X		X		X	X				
NNE16	22823	Balmoral	X									
NNE20	22825	Decewsville	X									
NNE22	22960	Dufferin North							X			X
NNE39	22902	Binbrook West	X	X	X	X			X		X	X
NE16	22957	Fisherville North							X	X		
NE19	22832	Kohler Road	X									
NE27	22956	Canfield South							X			X
NE41	22958	Canboro East							X			X
ENE11	22841	Selkirk	X						X			X
ENE17	22955	Rainham Centre South							X	X		
ENE18	22842	Rainham Center	X									
E04	22952	Peacock Point Park							X	X		
EO5	22851	Peacock Point	X									
SW37	22901	Long Point Park	X	X	X	X			X		X	
SW40	22959	Big Creek							X	X		
W07	22953	Dogs Nest East							X	X		
W13	22861	Port Dover	X									X
WNW03	22871	Nanticoke Village	X				X					
WNW19	22071	Simcoe Horticultural	X	X	X							
WNW20	22872	Bloomsburg	X									
NW03	22961	Nanticoke North							X	X		
NNW06	22963	Stelco North							X	X		
NNW08	22905	Nanticoke Road					X	X				
NNW11	22882	Jarvis	X									
NNW15	22884	Livingston	X									
NNW18	22954	Villa Nova							X			X
NE07	22962	Dry Creek --- Acoustic Sounder Site										
NNW12	22883	Jarvis Met Tower --- Meteorological Tower Site										

**Table 2**  
**Ambient Air Quality Criteria in Ontario**

Contaminant	Unit of Measure	Aver. Amt. of Conc.	Time Period
Sulfur Dioxide	parts of SO <sub>2</sub> per	250	1 hour
	1 billion parts	100	24 hour
	of air by volume	20	1 year
Nitrogen Dioxide	parts of NO <sub>2</sub> per	200	1 hour
	1 billion parts	100	24 hour
	of air by volume		
Ozone	parts of O <sub>3</sub> per	80	1 hour
	1 billion parts		
	of air by volume		
Total Suspended Particulates	micrograms of sus- pended particulates	120	24 hour
	matter per cubic	60 (geos.	1 year
	metre of air	mean)	

Figure 1  
Monitoring Stations in the Haldimand-Morfolk Region

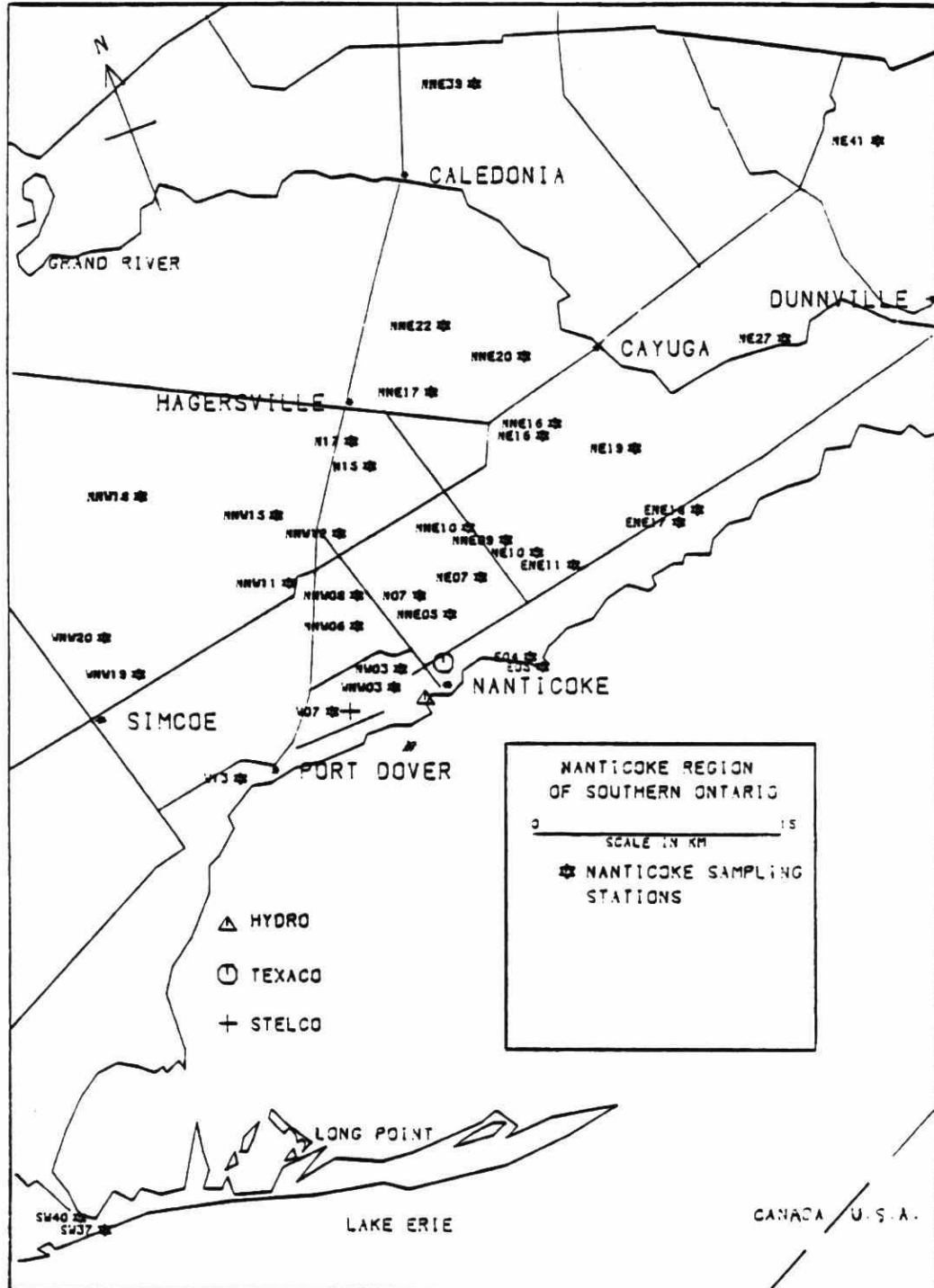


Figure 2  
Annual SO<sub>2</sub> Emissions for Ontario Hydro, Texaco and Stelco

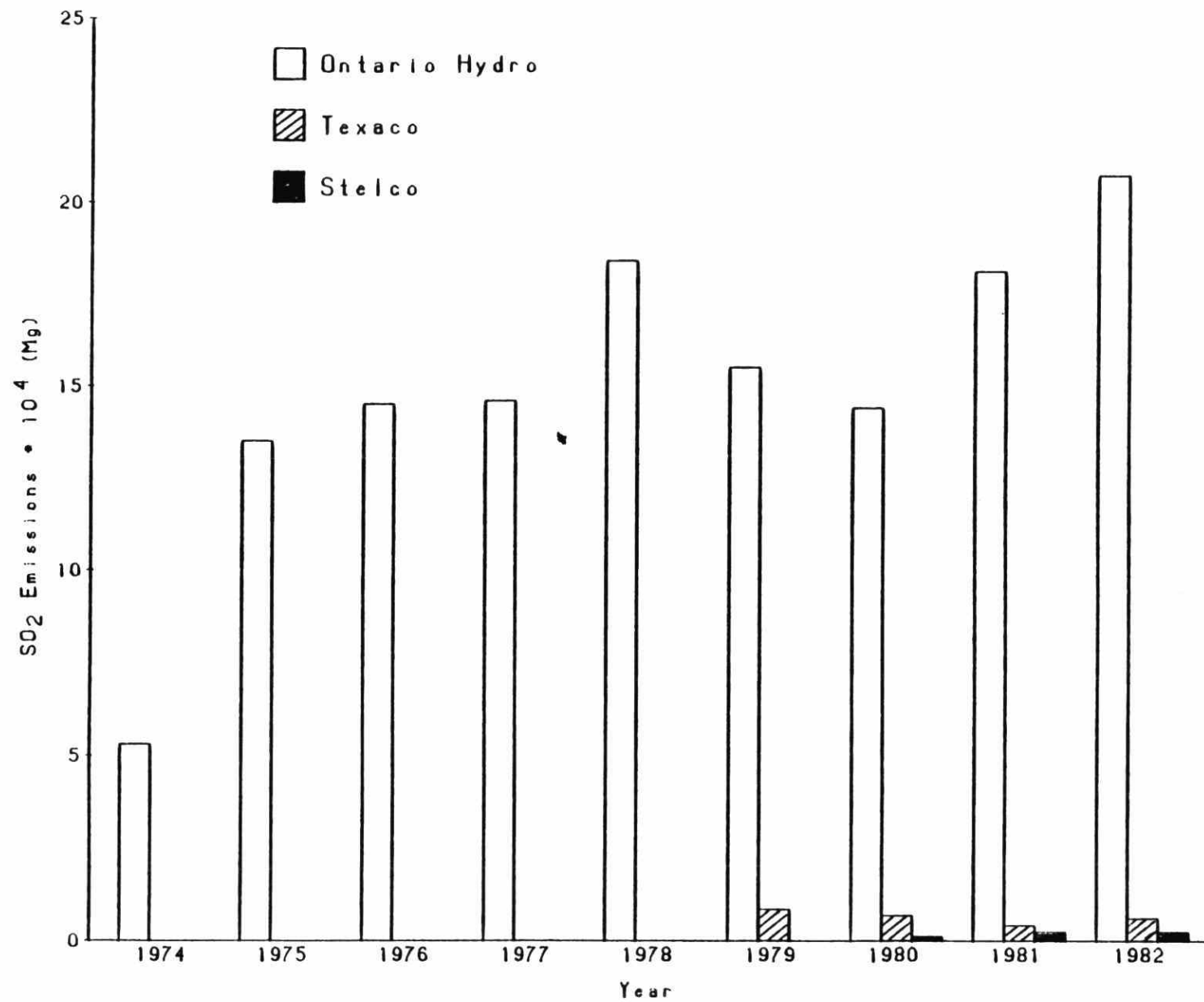


Figure 3

Annual TSP Emissions for Ontario Hydro, Texaco and Stelco

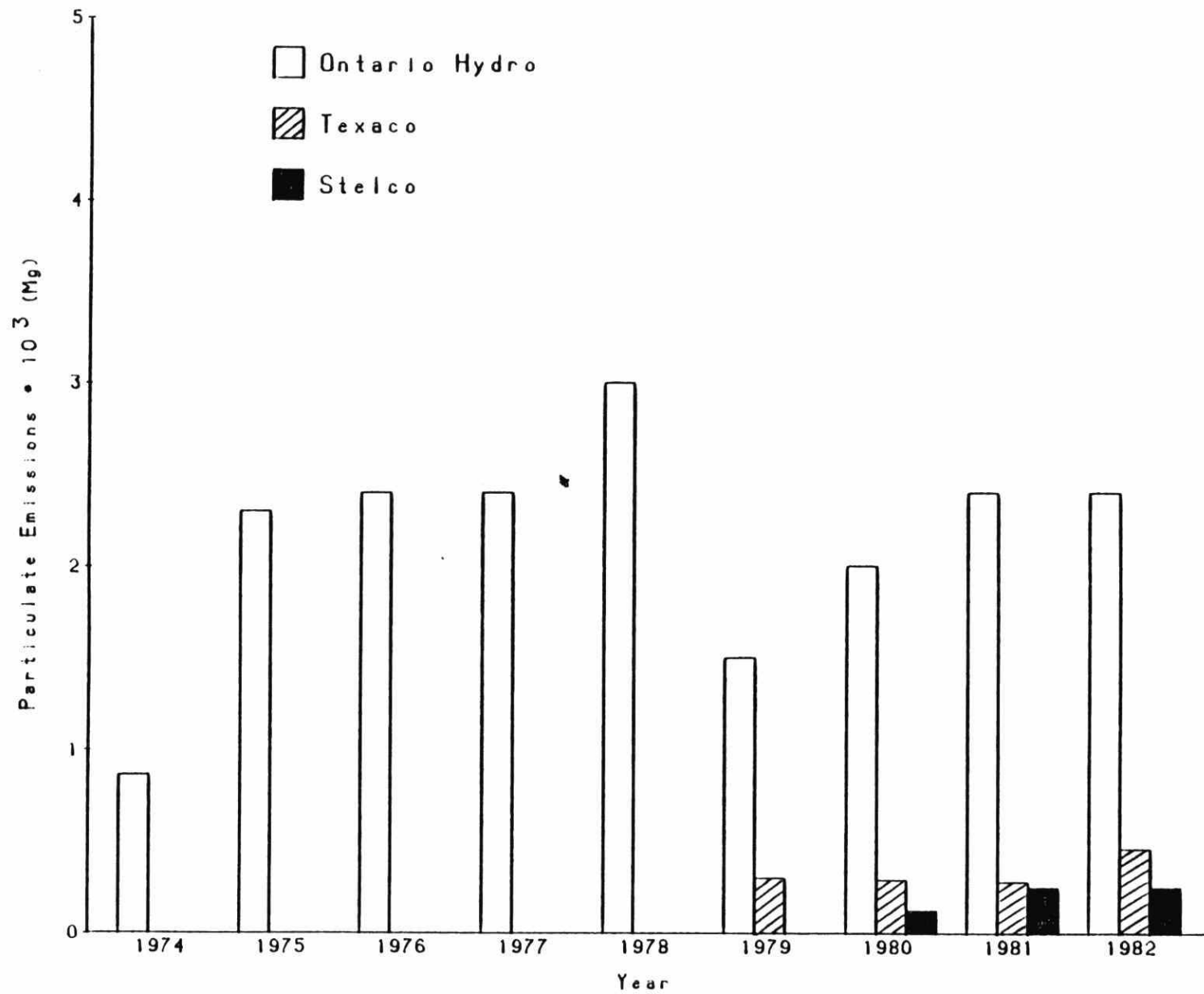




Figure 4  
Annual NO Emissions for Ontario Hydro, Texaco and Stelco

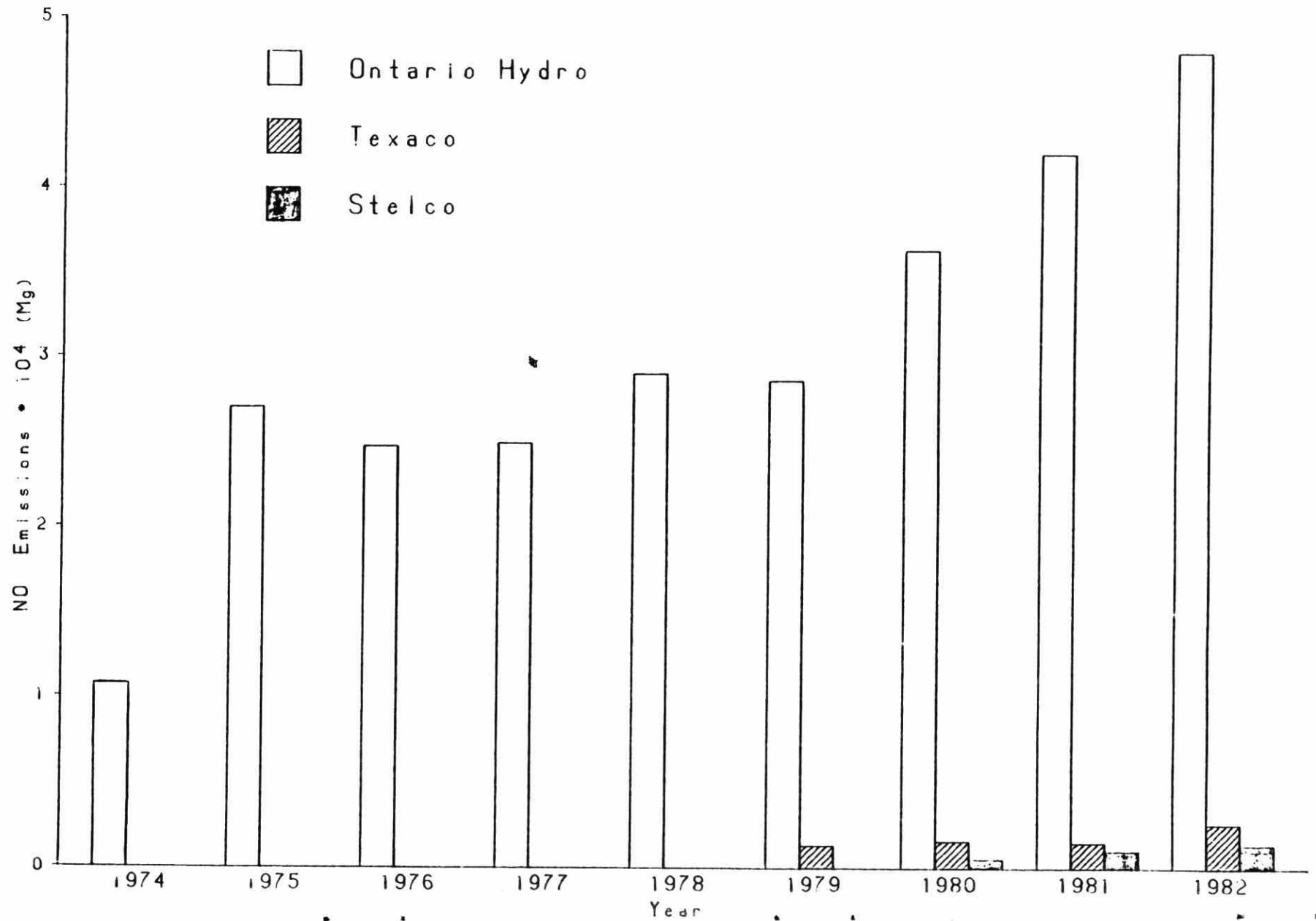


Figure 5  
Trend of SO<sub>2</sub> in the Haldimand-Norfolk Region - 1975 to 1982

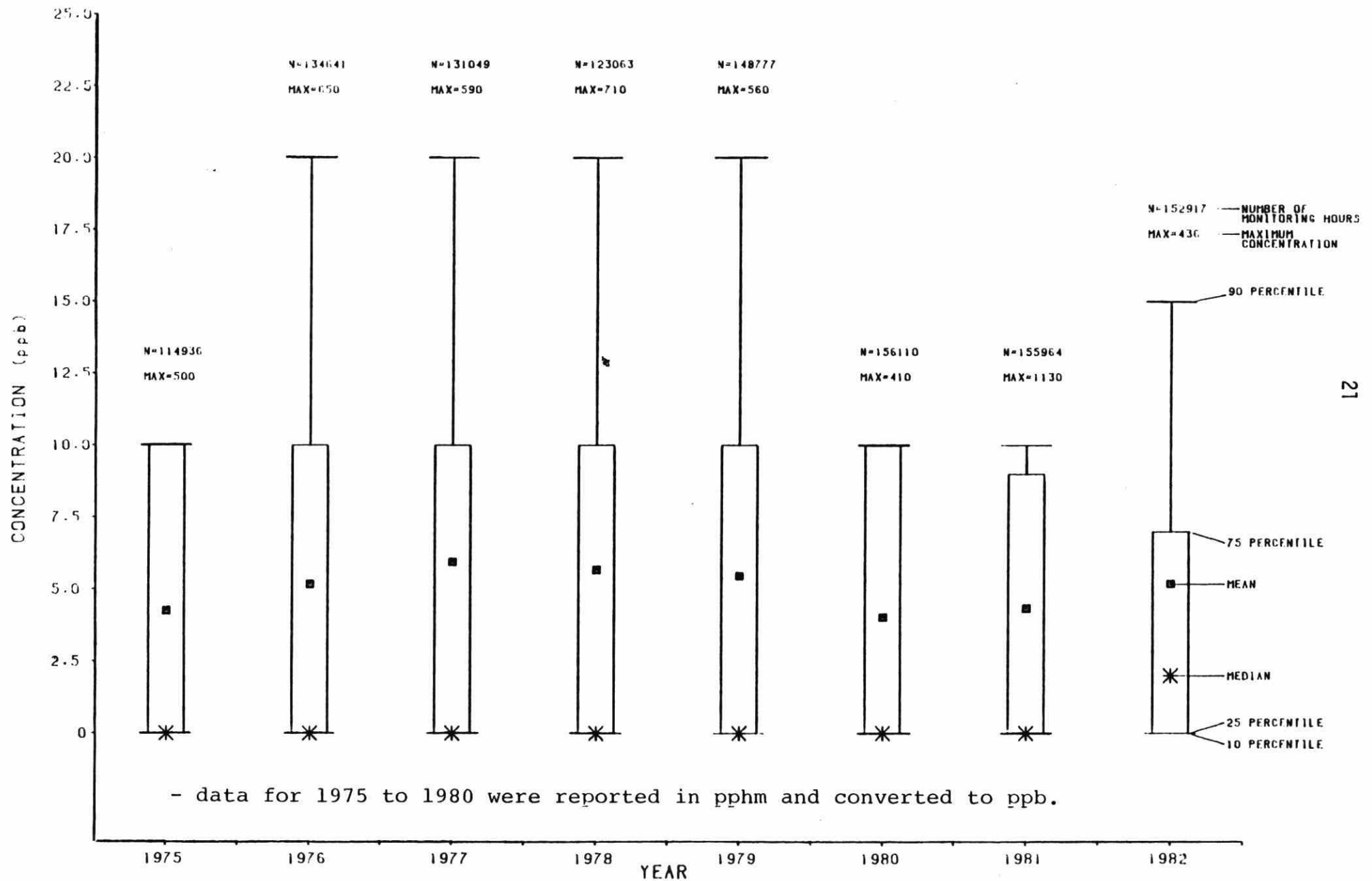


Figure 6

Trend of TSP in the Haldimand-Norfolk Region - 1979 to 1982

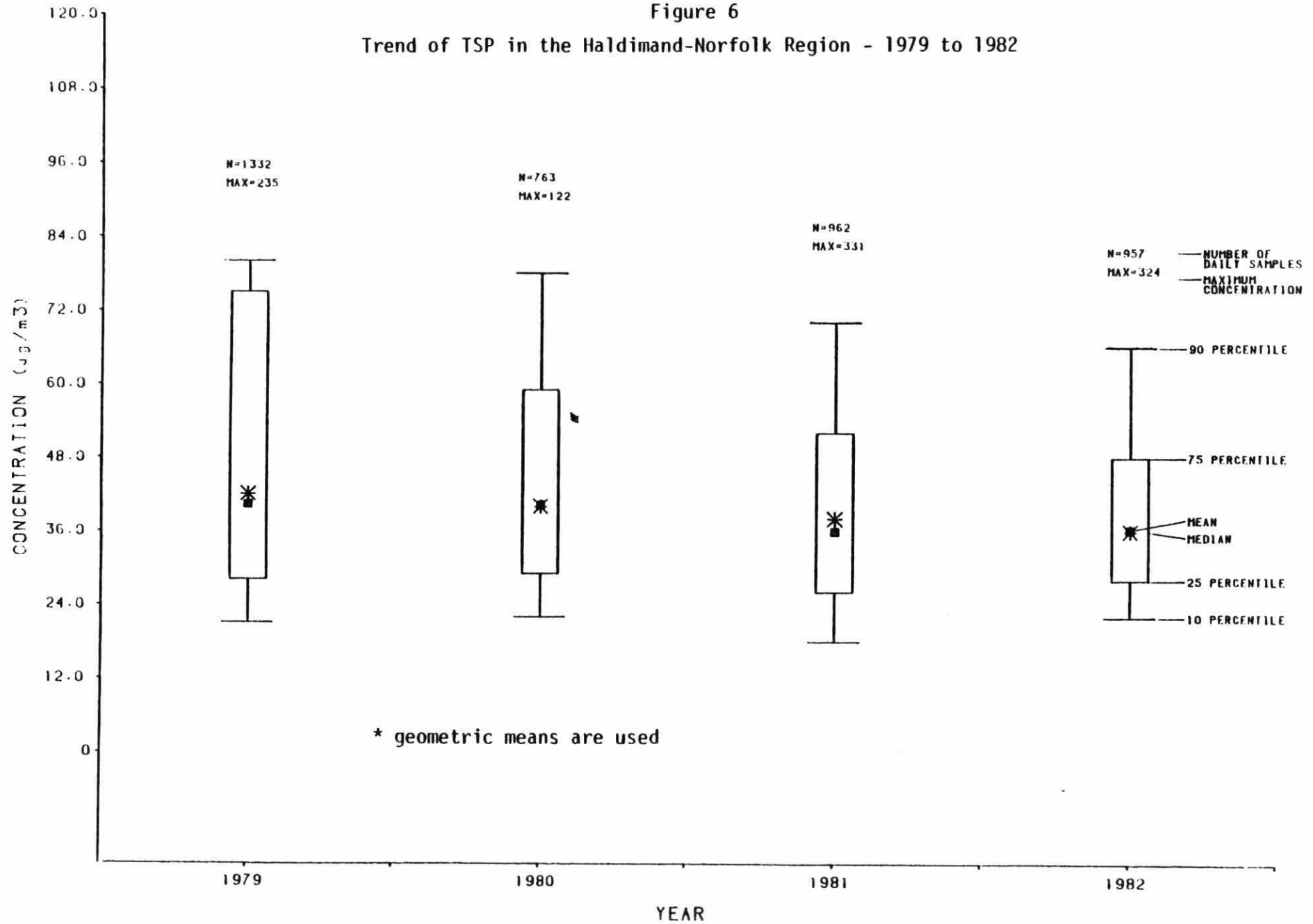


Figure 7  
Trend of  $O_3$  in the Haldimand-Norfolk Region - 1979 to 1982

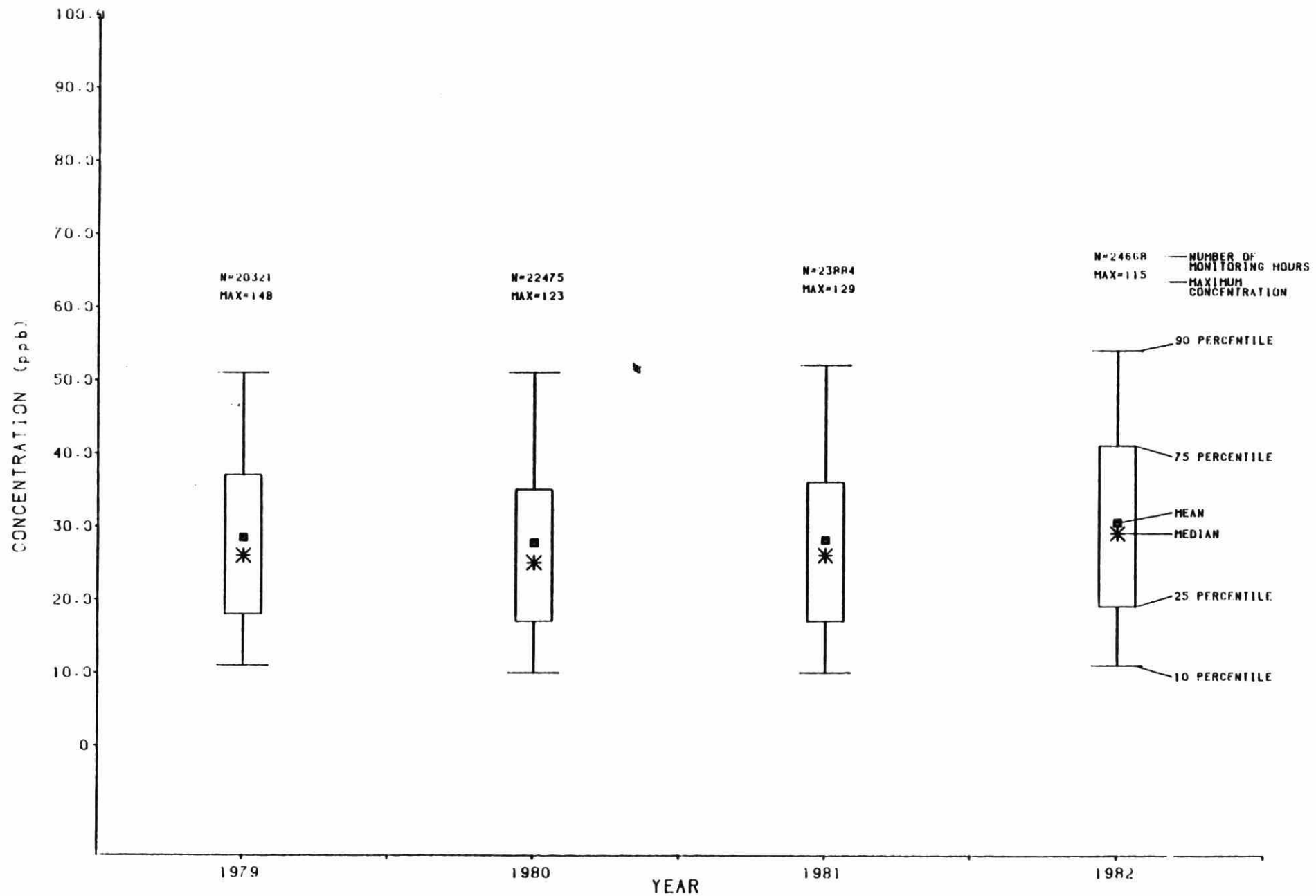


Figure 8  
Trend of NO<sub>2</sub> in the Haldimand-Norfolk Region - 1979 to 1982

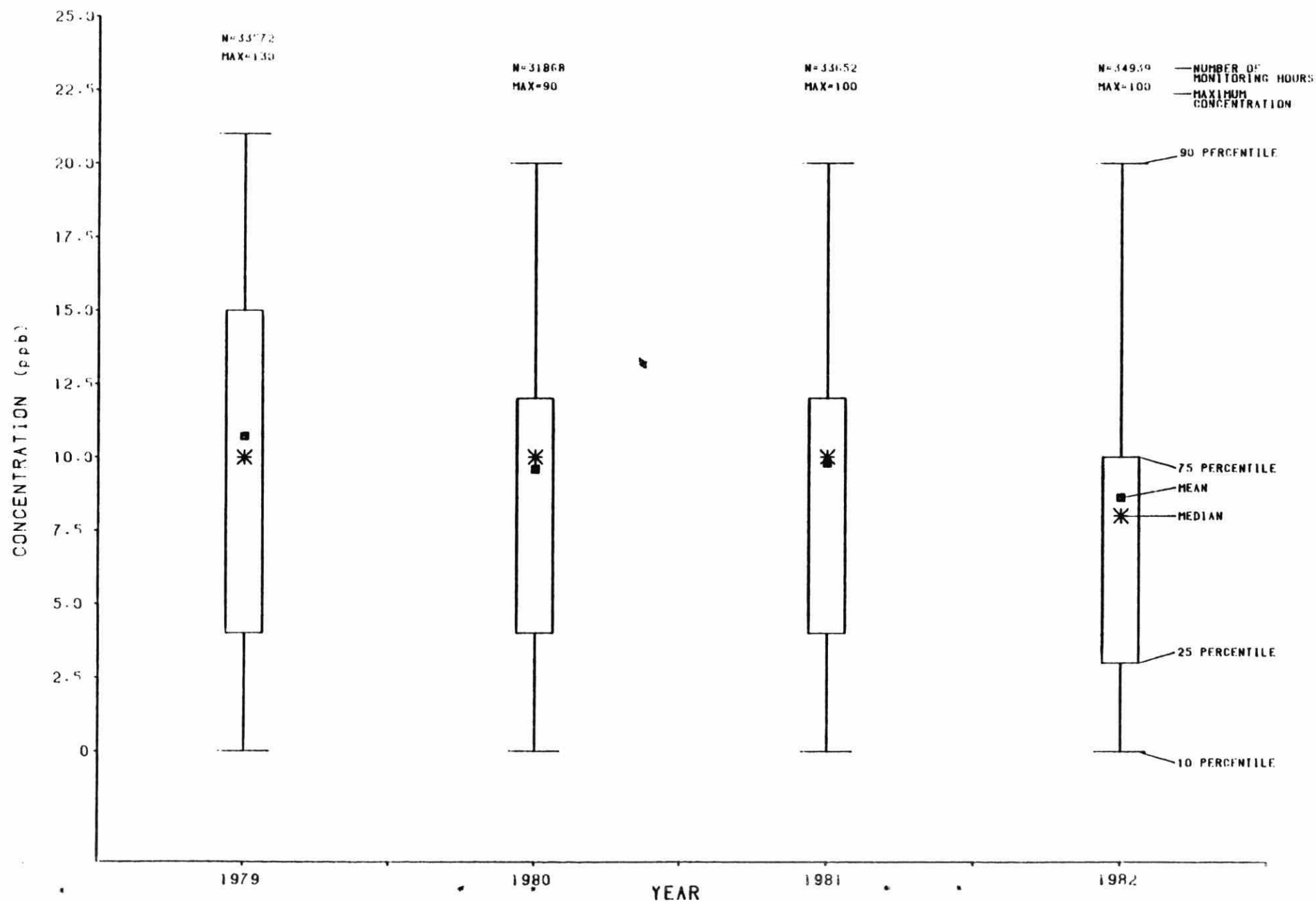


Figure 9  
Trend of TRS in the Haldimand-Norfolk Region - 1979 to 1982

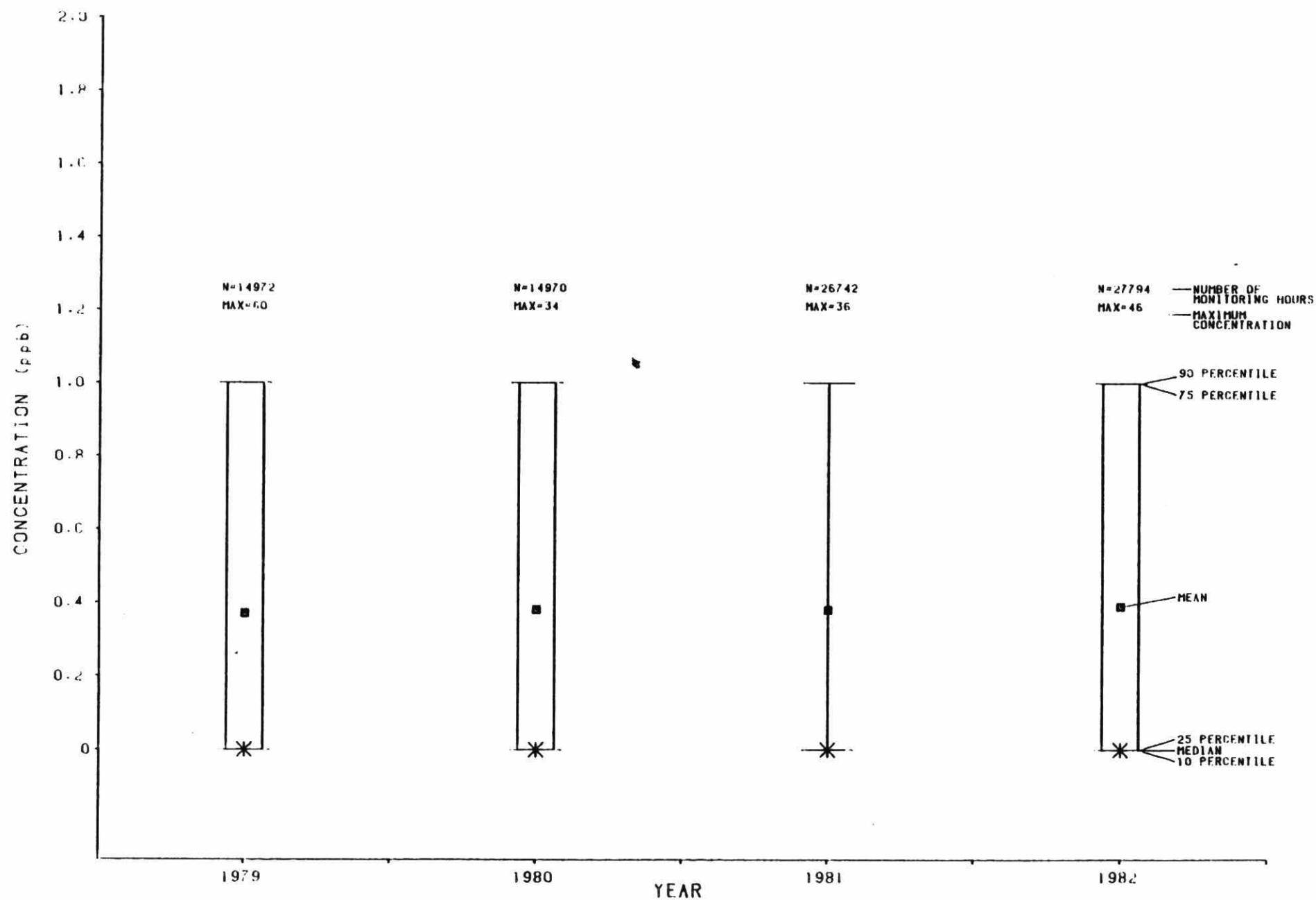


Figure 10  
Trend of NMHC in the Haldimand-Norfolk Region - 1979 to 1982

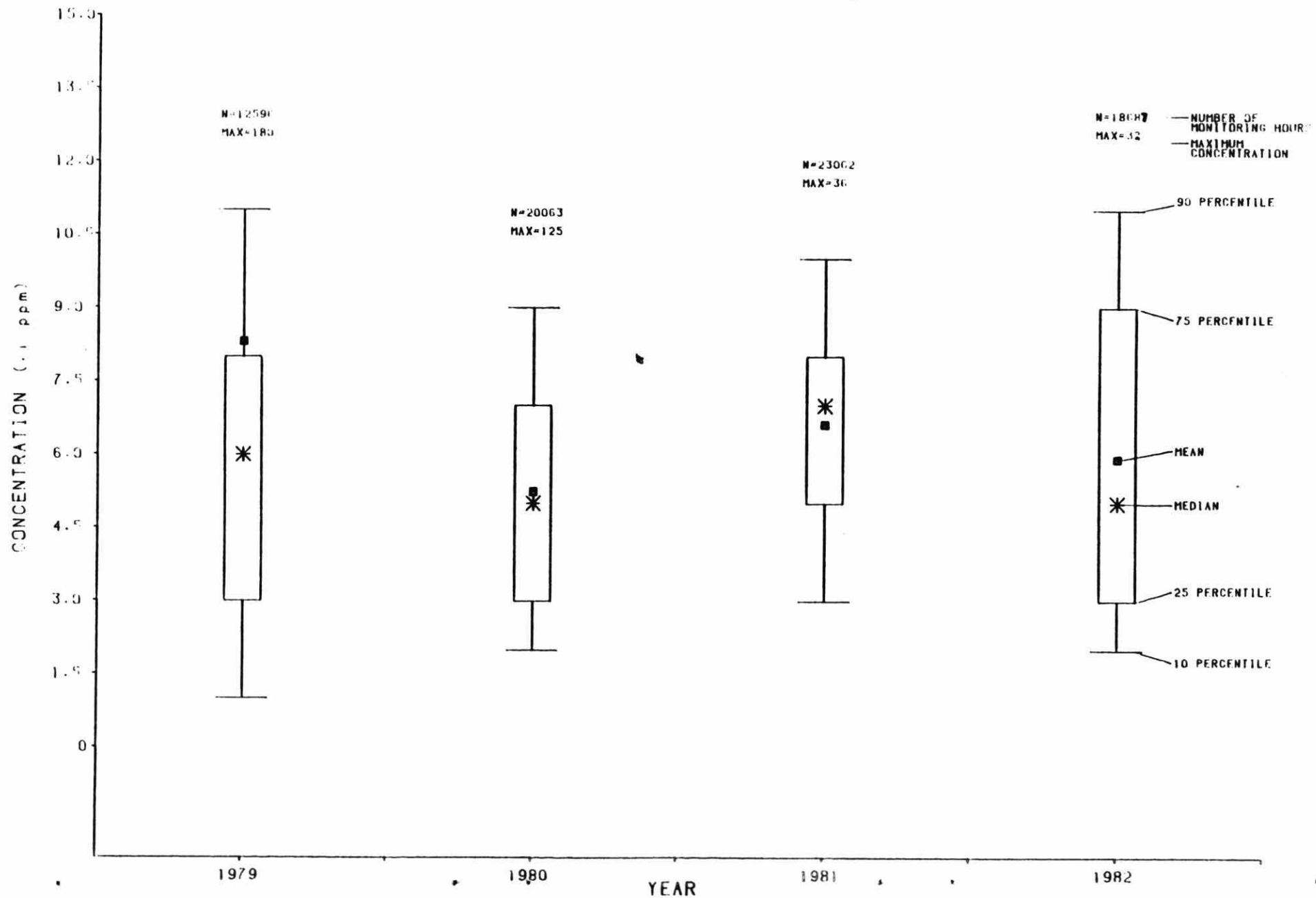


Figure 11  
Trend of CH<sub>4</sub> in the Haldimand-Norfolk Region - 1979 to 1982

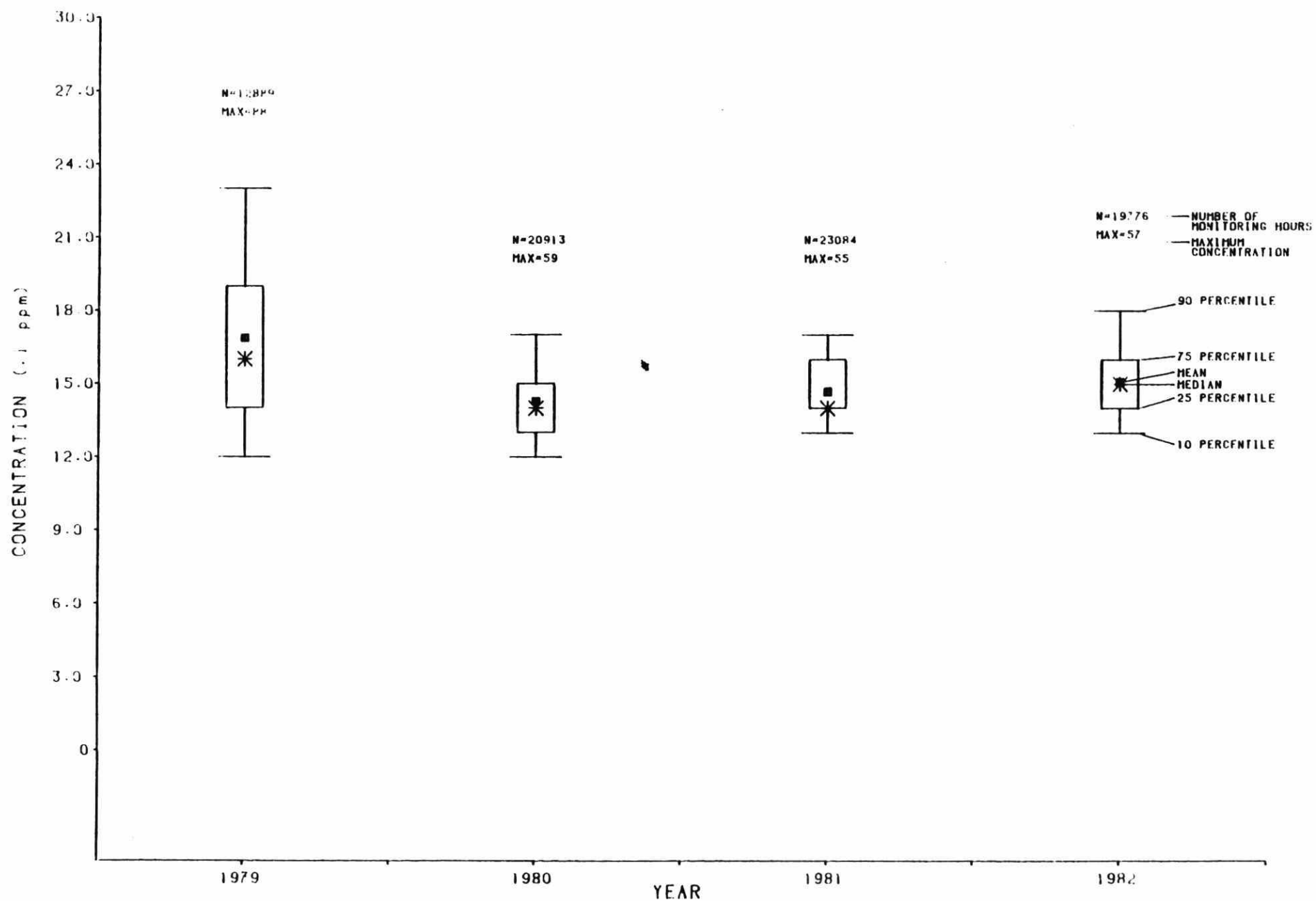




Figure 12

SO<sub>2</sub> Multi-Year Average - 1975 to 1982

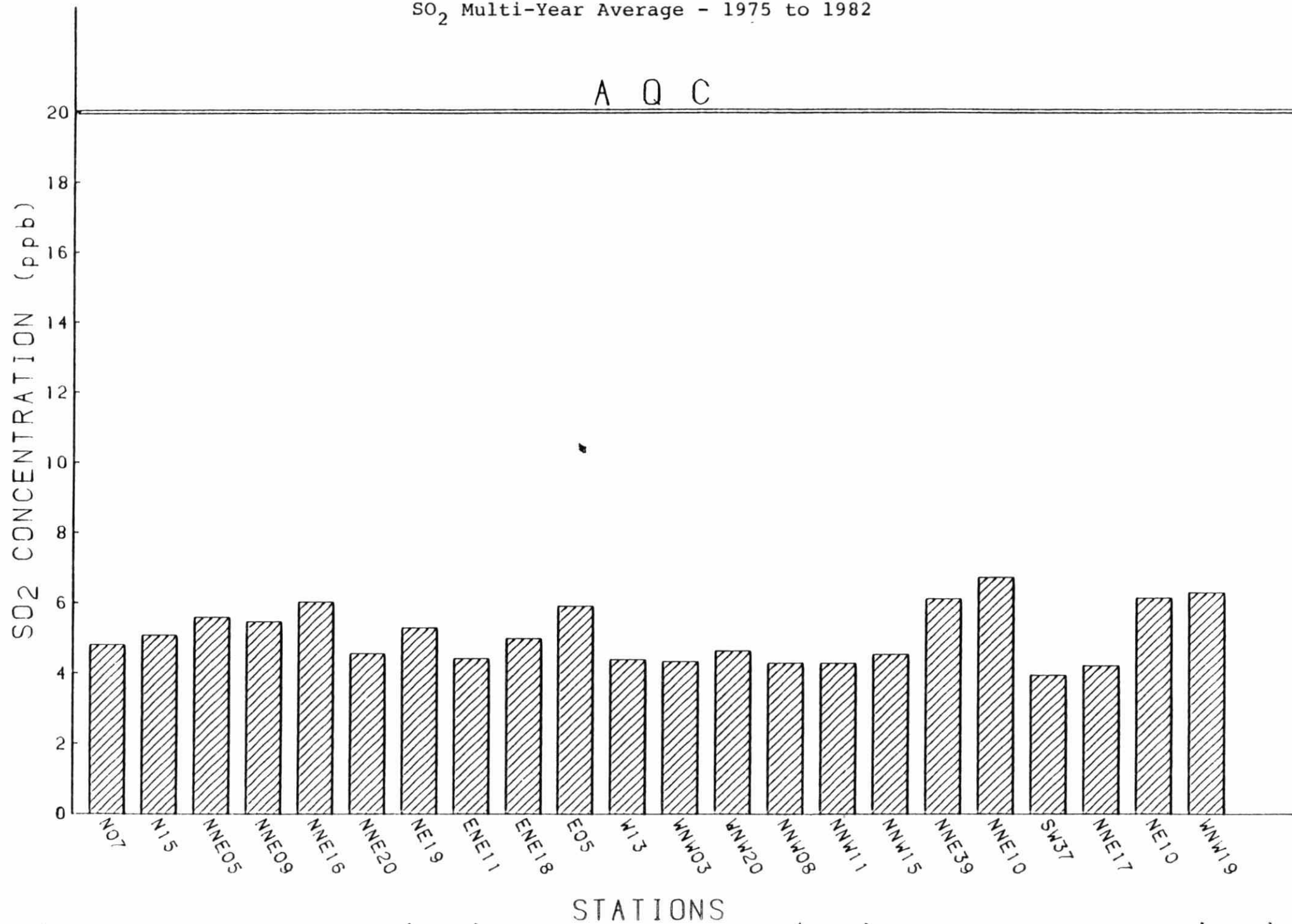


Figure 13  
Network Hourly SO<sub>2</sub> Exceedances by Year

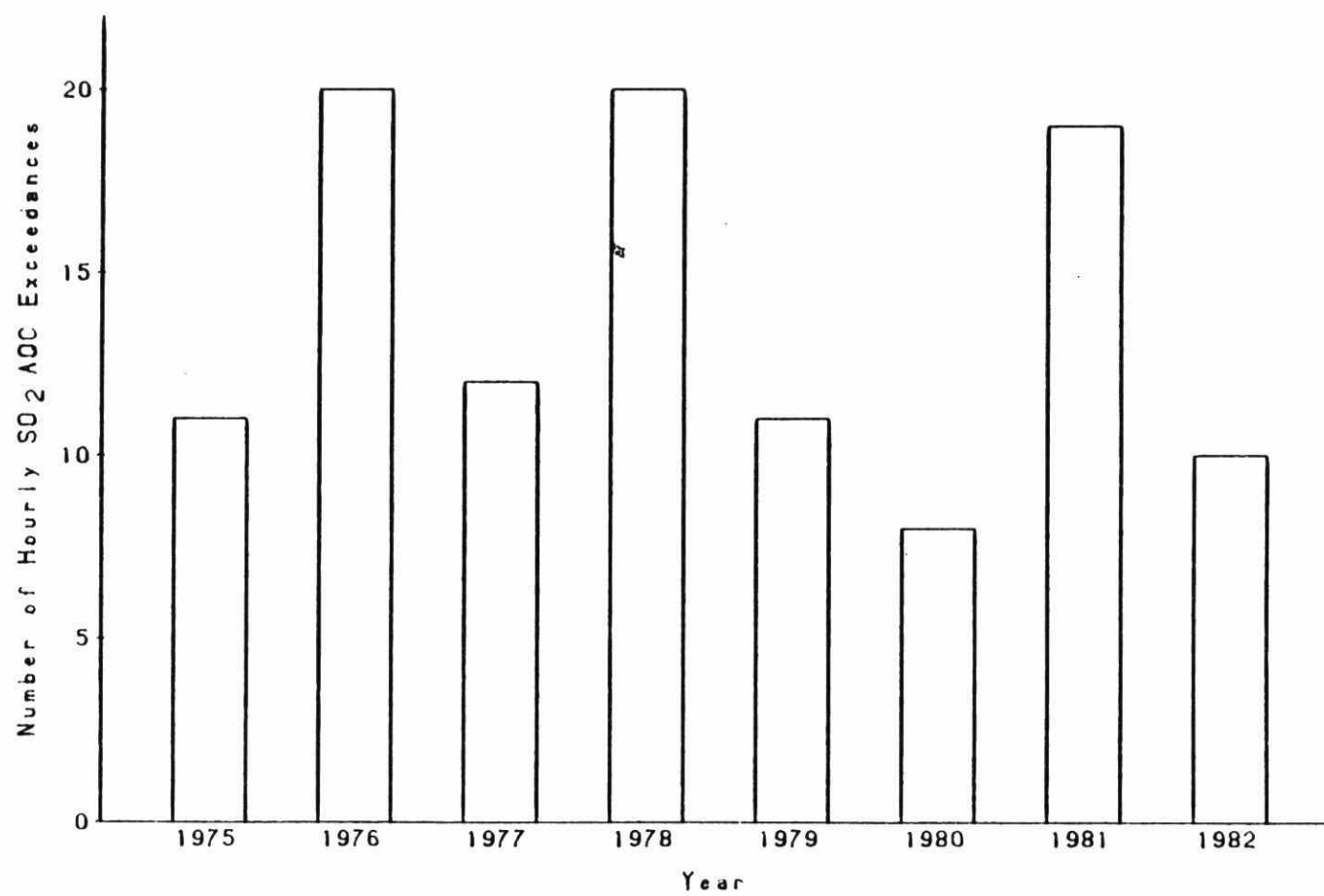


Figure 14

Seasonal Distribution of  
Network Hourly SO<sub>2</sub> Exceedances

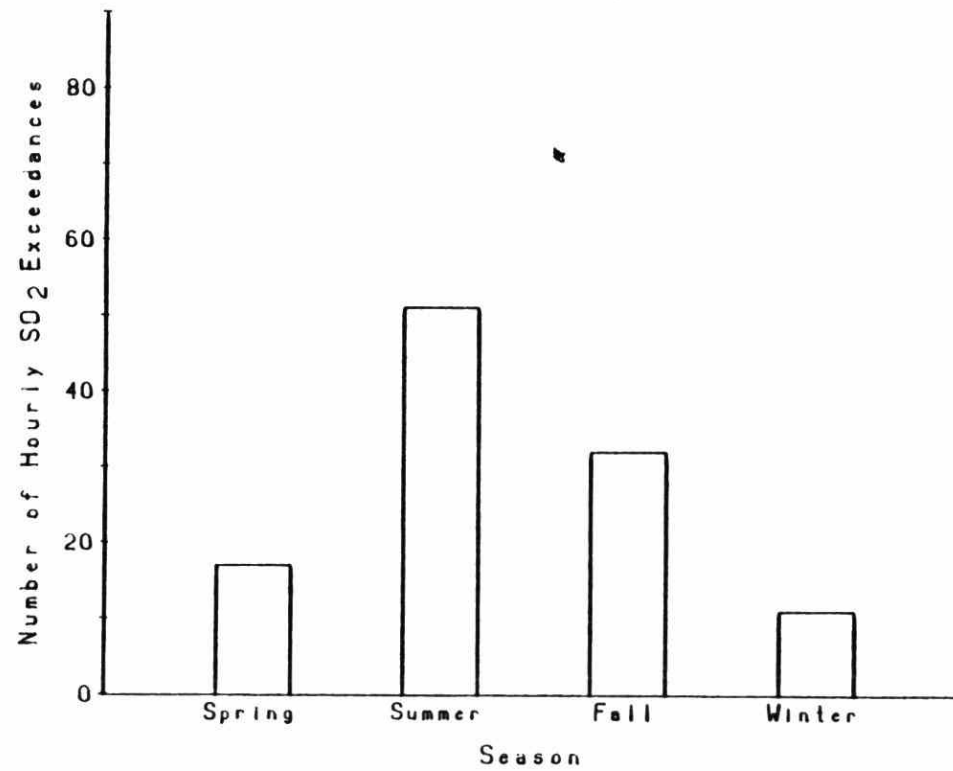


Figure 15  
TSP Geometric Mean Concentrations - 1979 to 1982

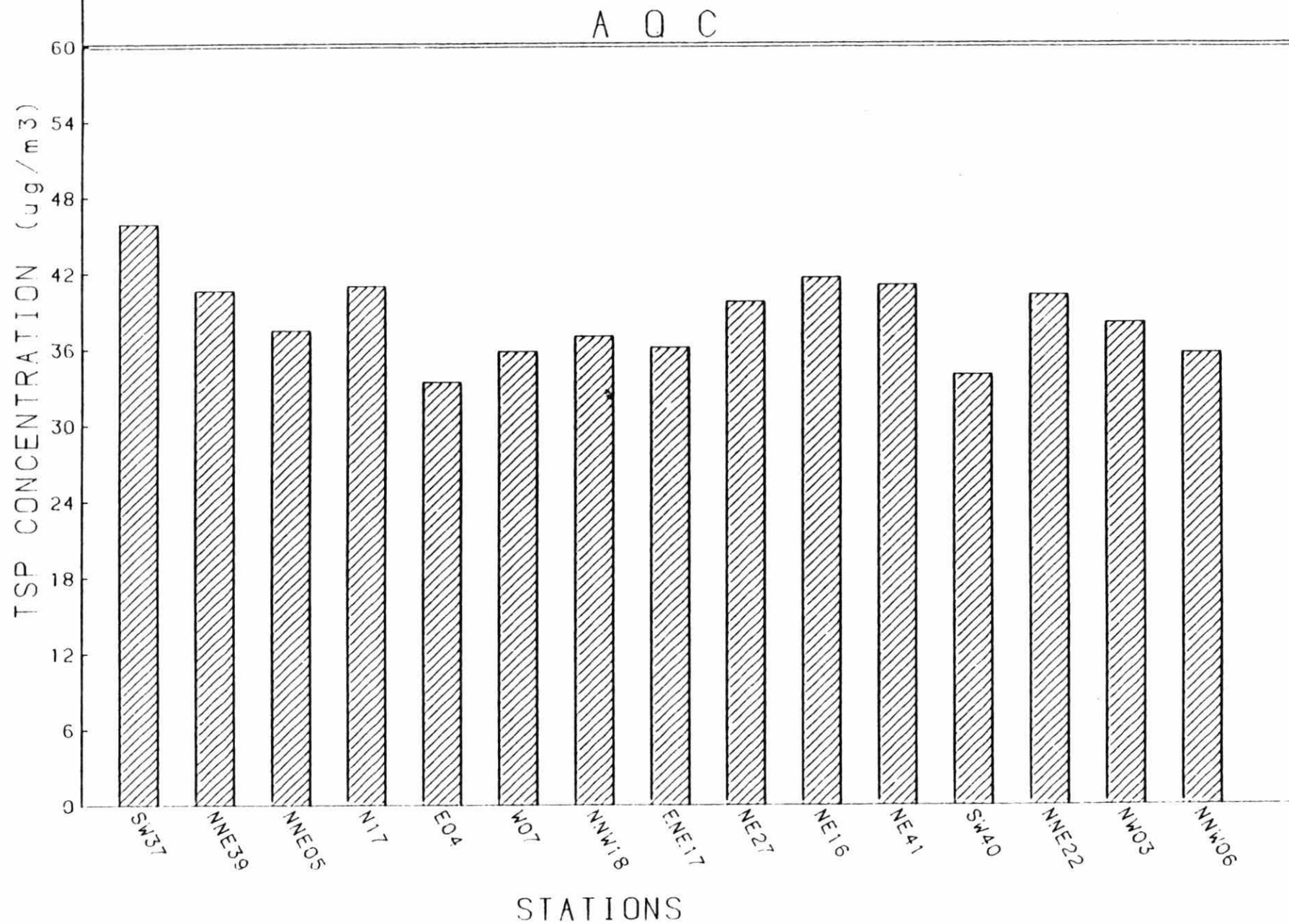


Figure 16  
Network Daily Tsp Exceedances by Year

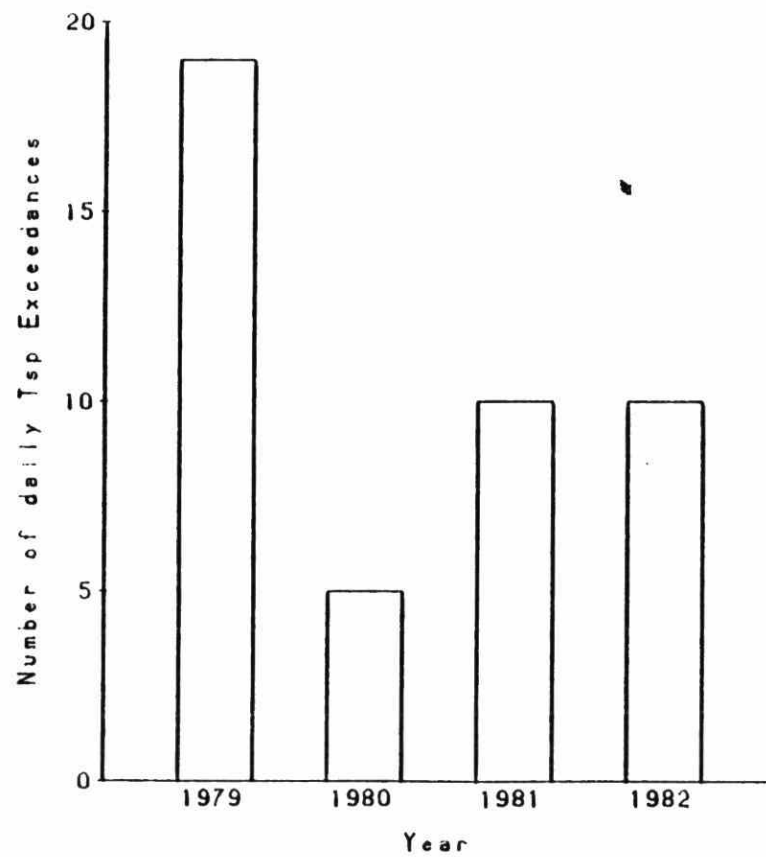
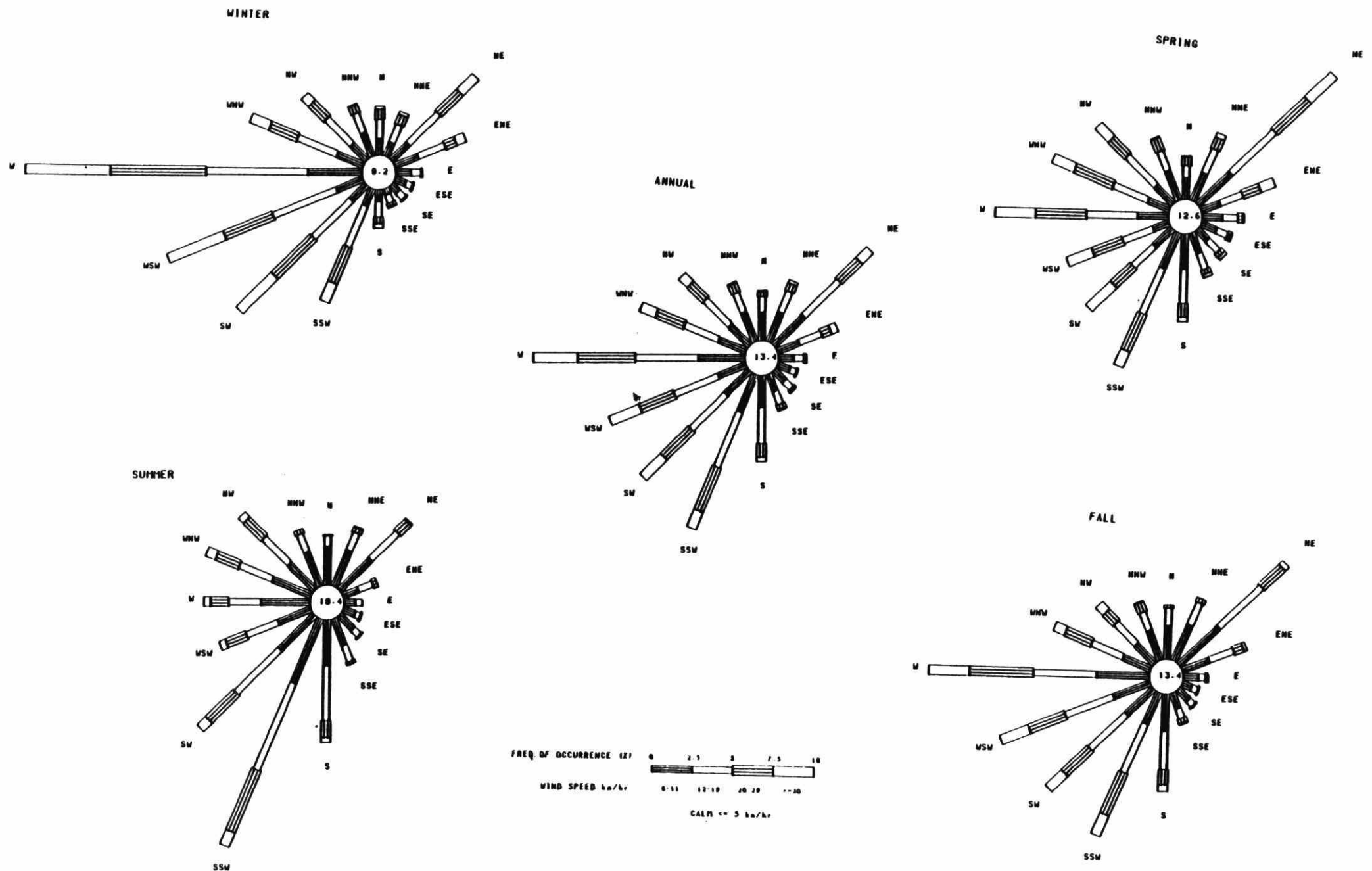


Figure 17

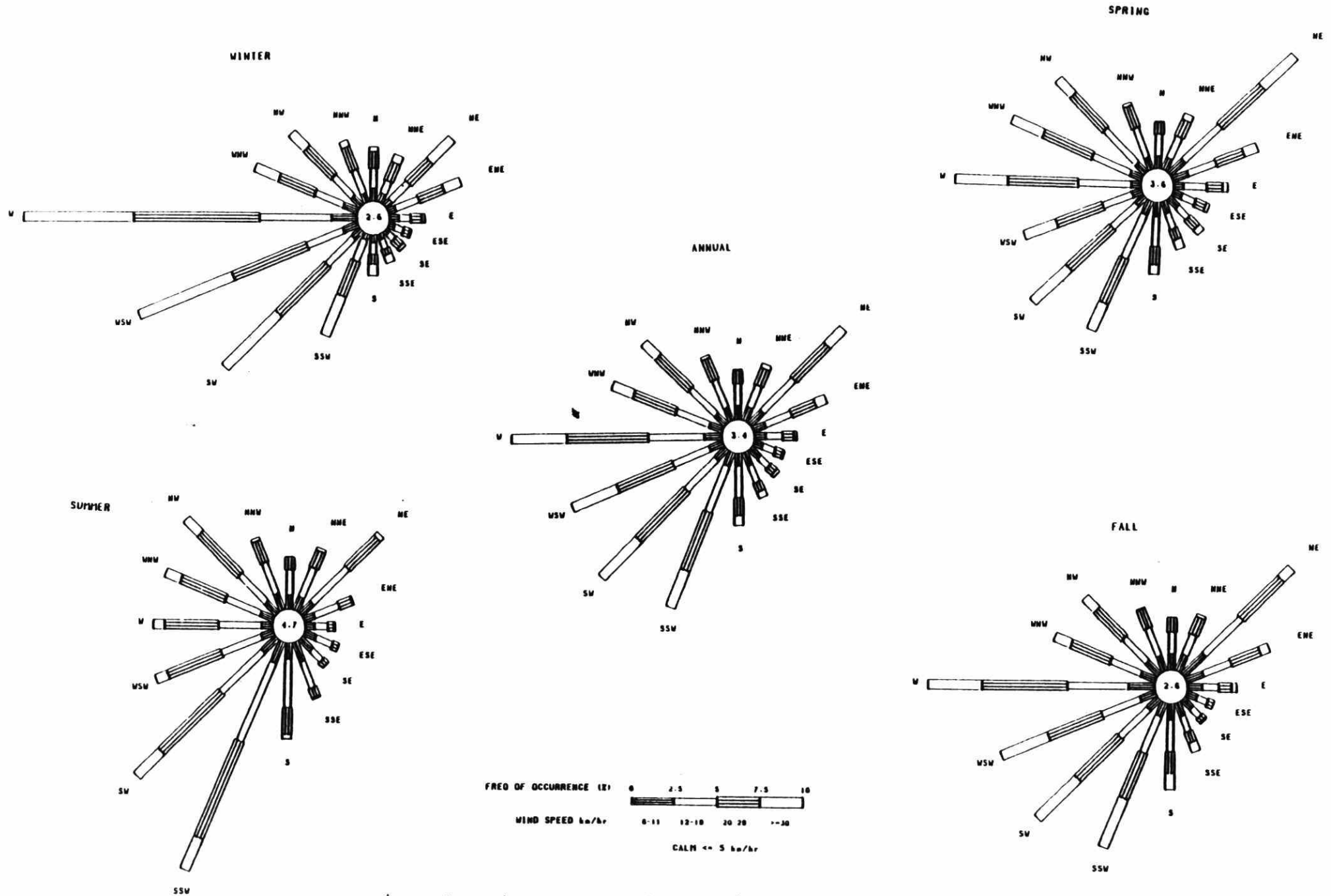
Annual and Seasonal Wind Roses - 10m Level Winds at the Jarvis Met Tower - 1975 to 1982



\* number in centre of rose is percentage of calm

Figure 18

Annual and Seasonal Wind Roses - 85m Level Winds at the Jarvis Met Tower - 1975 to 1982



\* number in centre of rose is percentage of calm

Figure 19  
Annual Distribution of Hourly Averaged Mixed Layer Heights  
According to Onshore/Offshore Flow

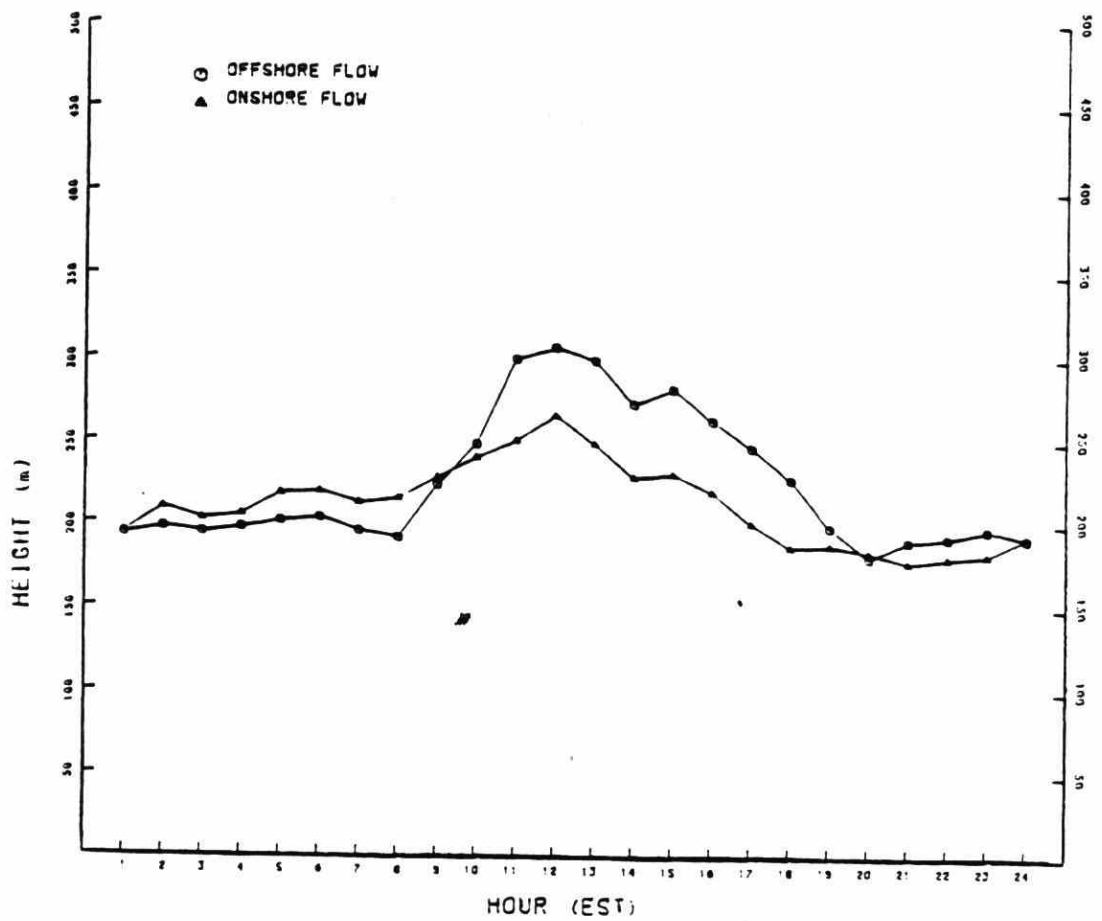
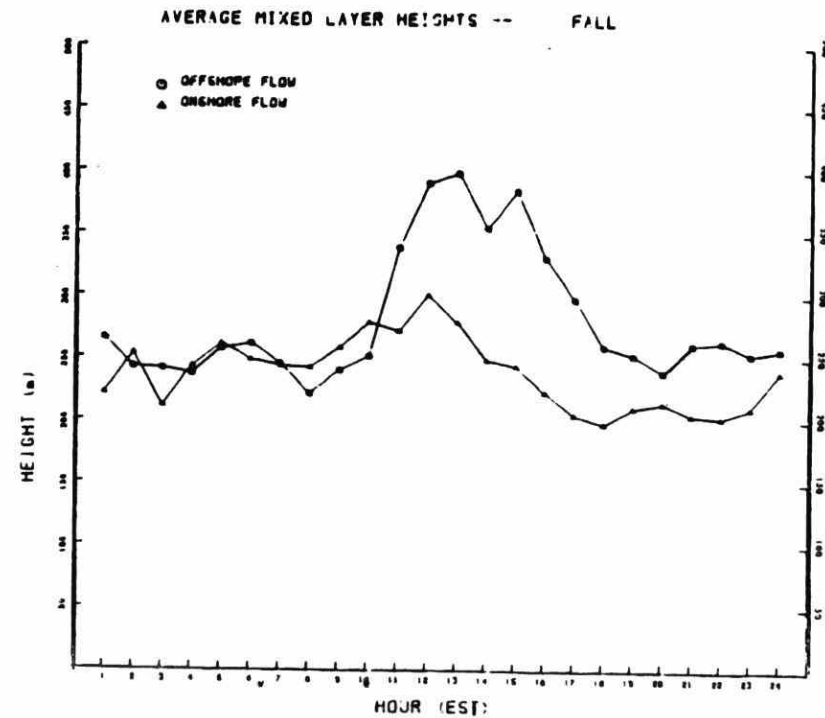
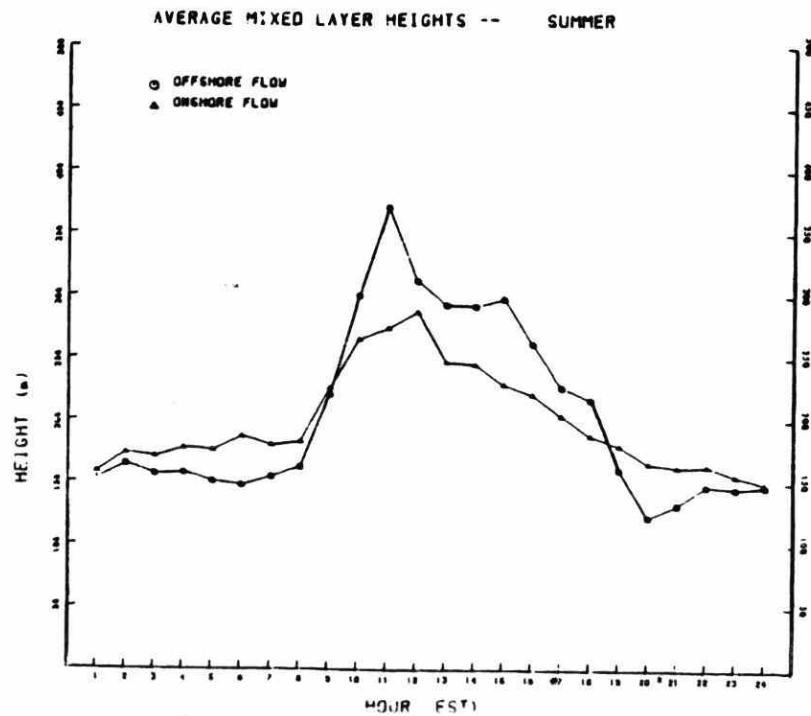
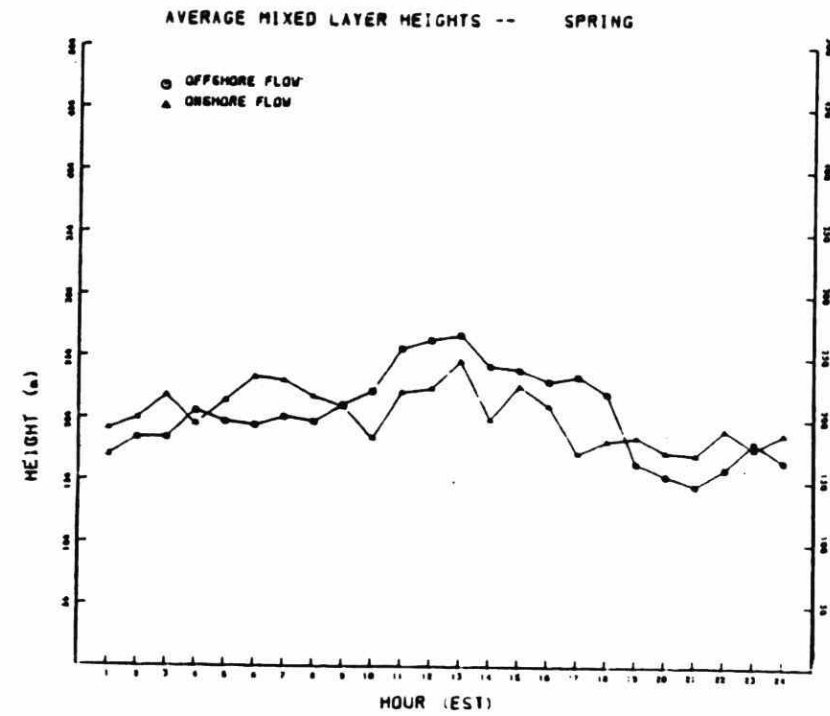
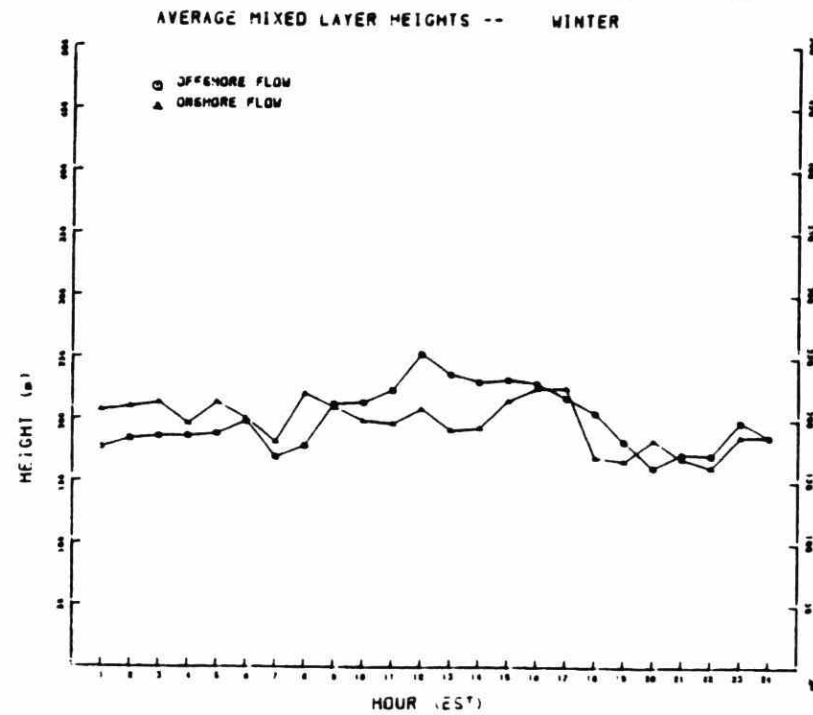
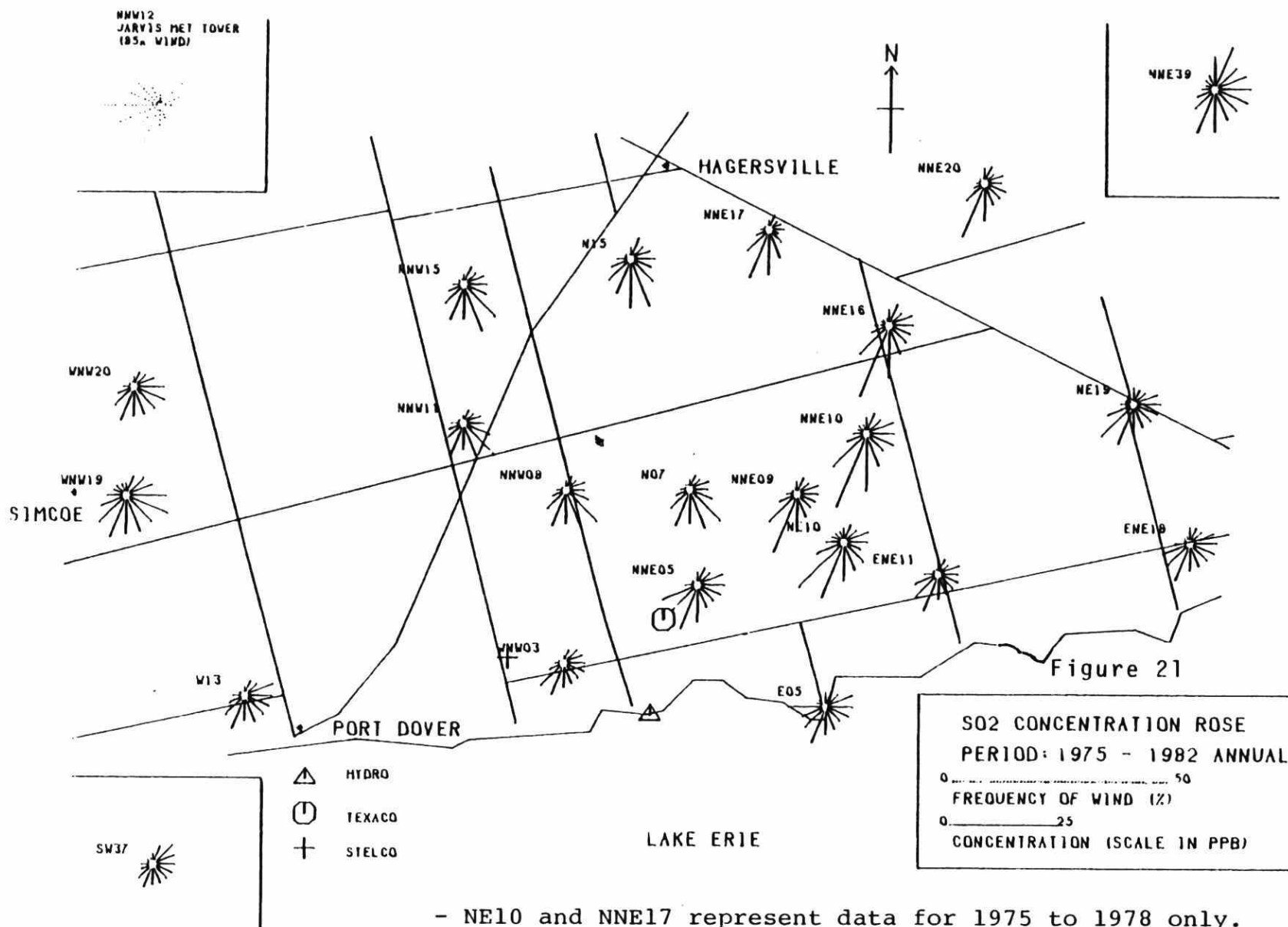




Figure 20

# Seasonal Distribution of Hourly Averaged Mixed Layer Heights According to Onshore/Offshore Flow





- NE10 and NNE17 represent data for 1975 to 1978 only.
- NNE05, NNE20, SW37 and NNE39 represent data for 1979 to 1982 only.

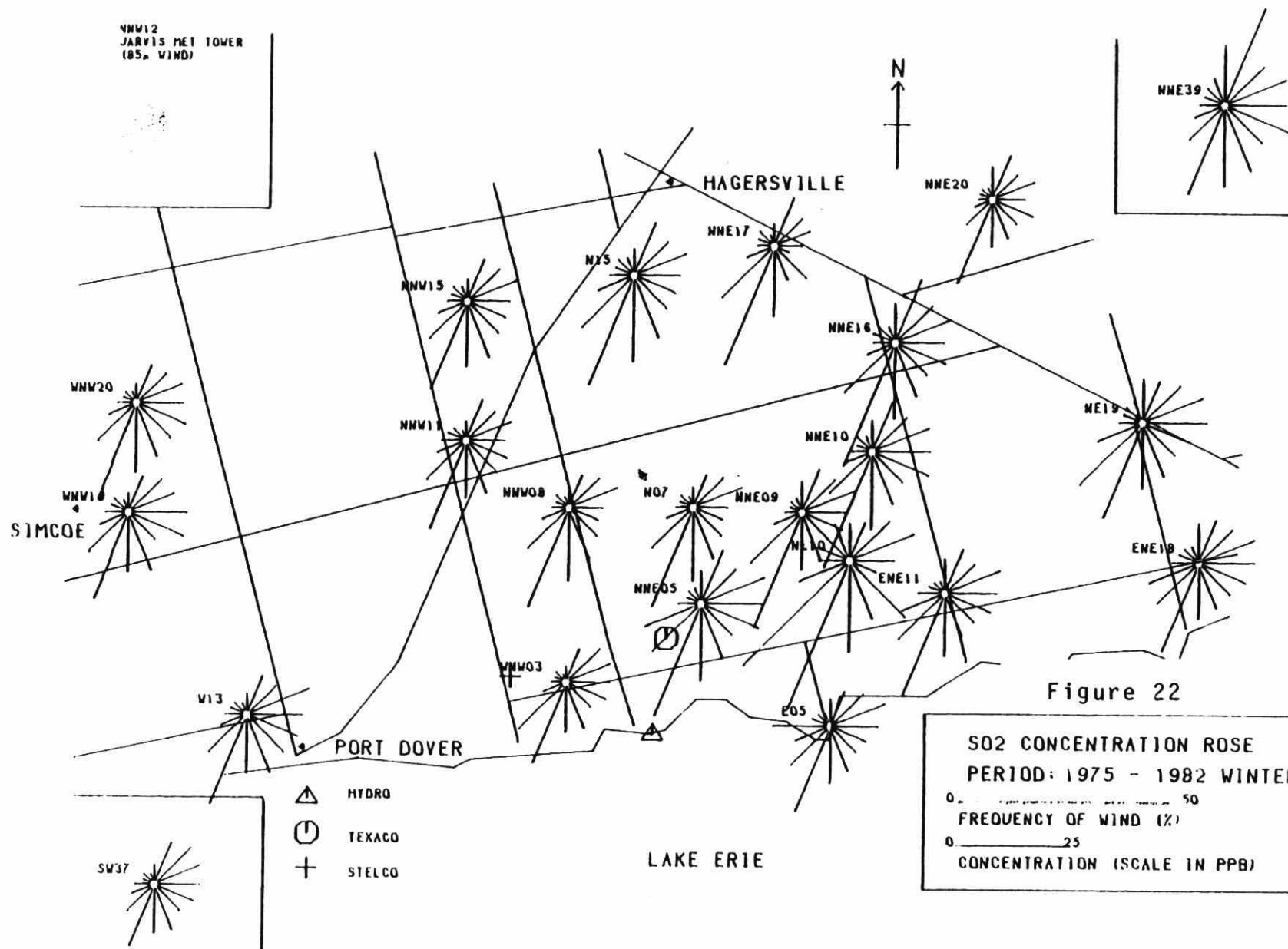
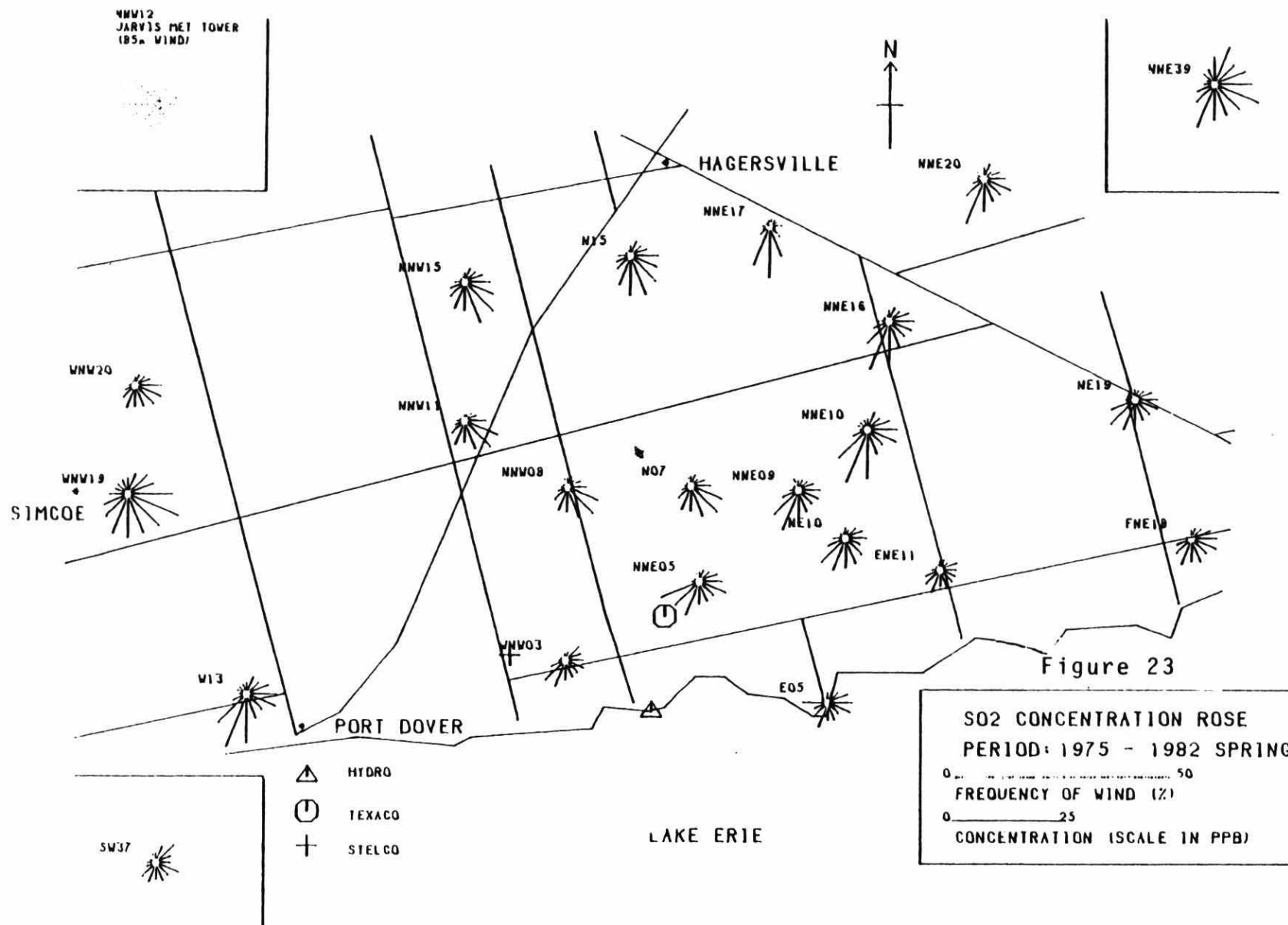
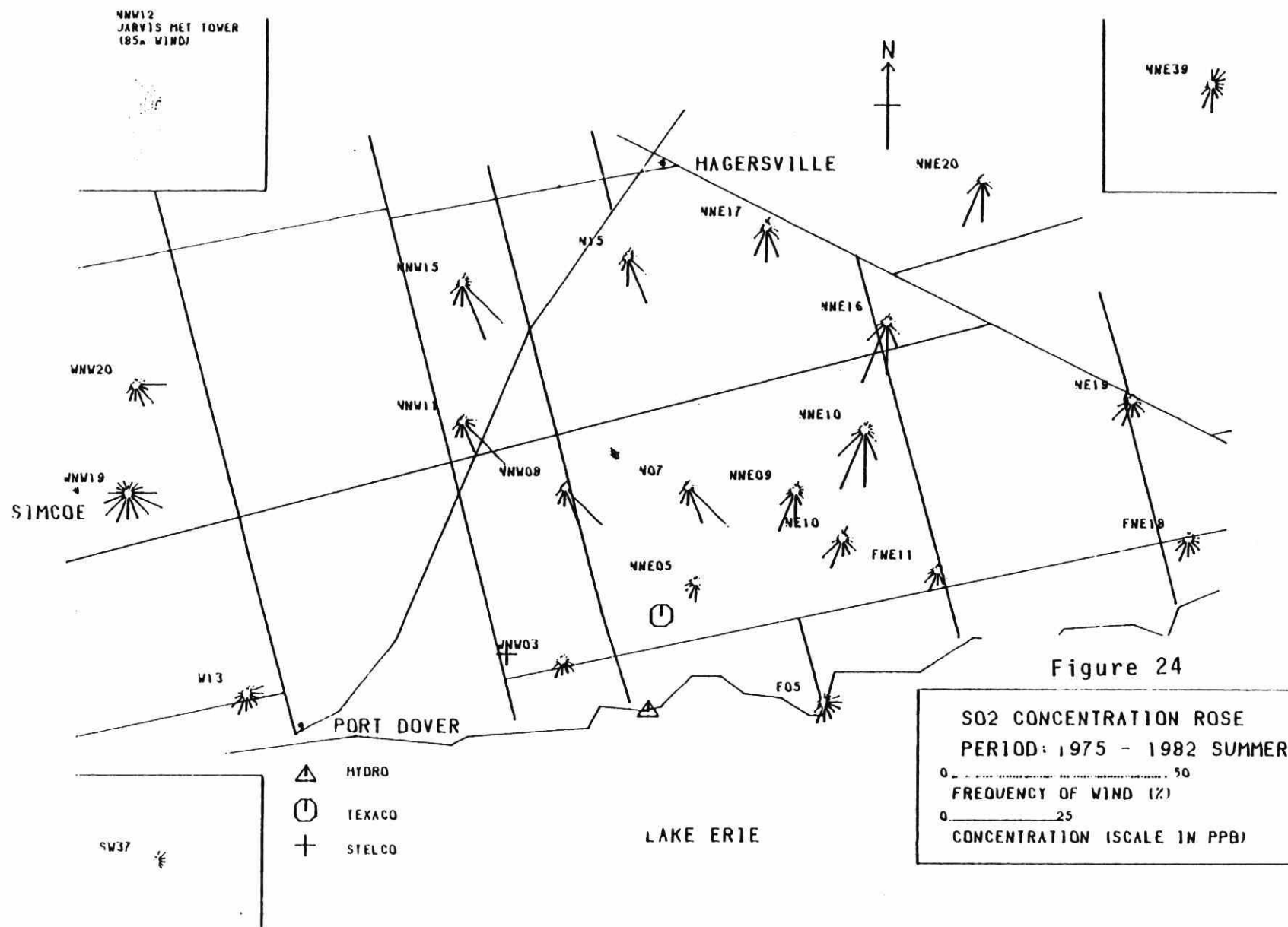
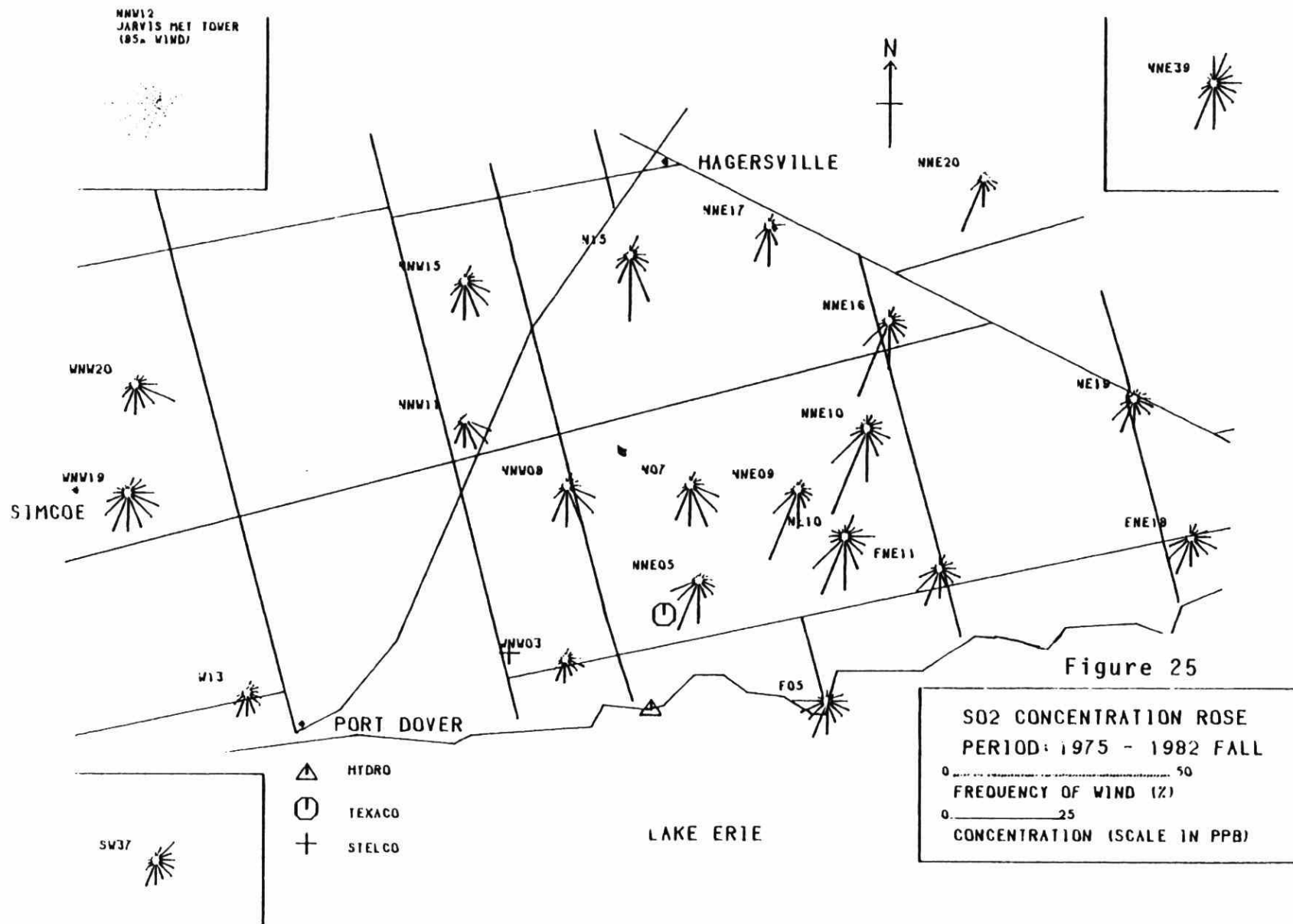
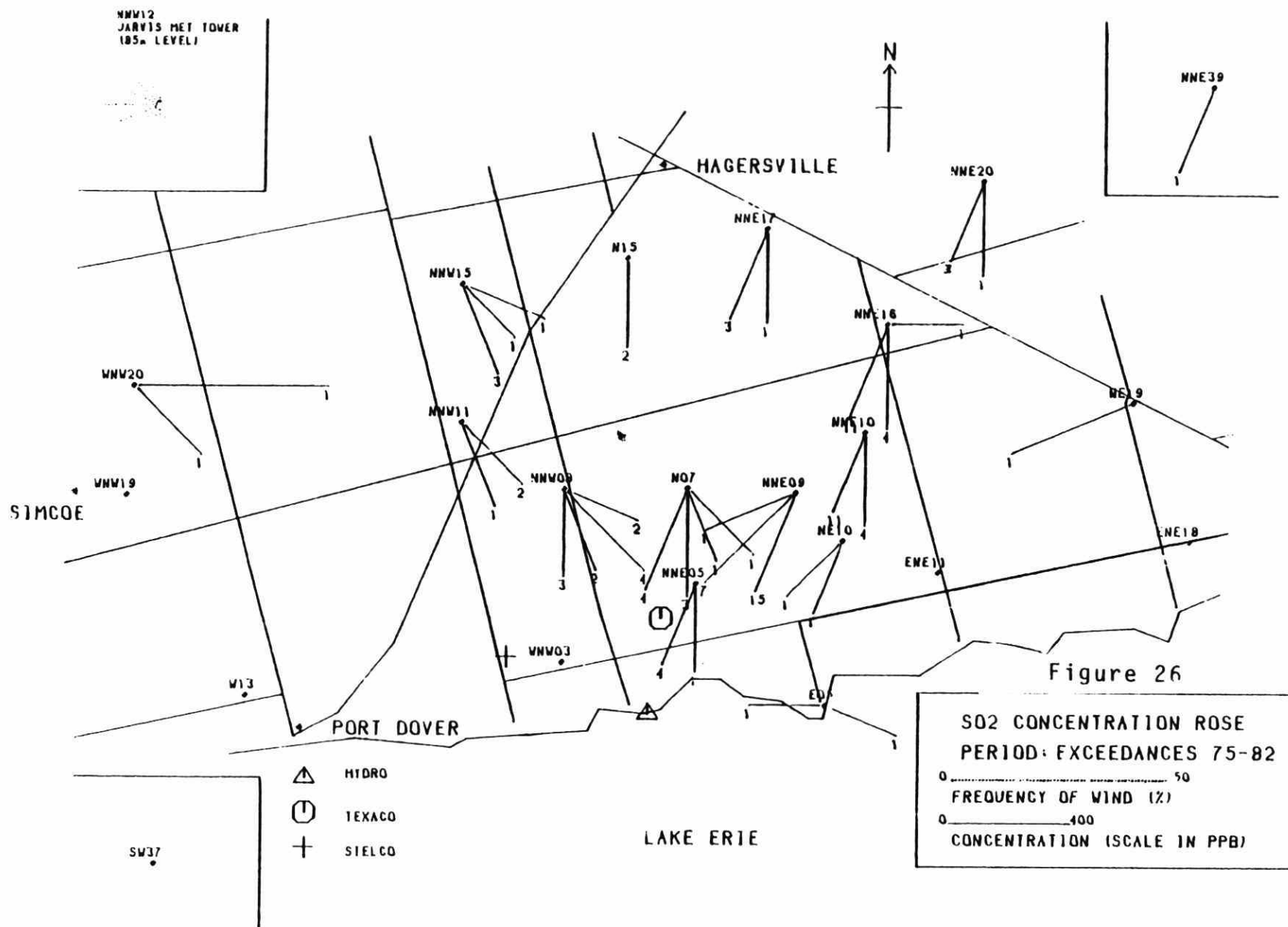


Figure 22









- The number of exceedances is marked at the end of each arm
- One exceedance occurred at W13 under calm conditions
- one exceedance occurred at NWV03 under calm conditions

WINTER

SPRING

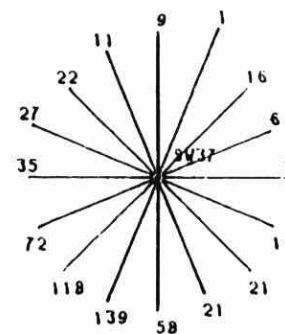
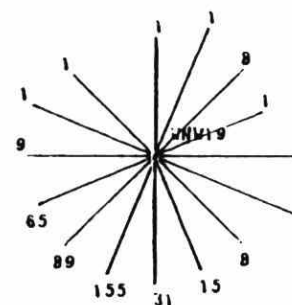
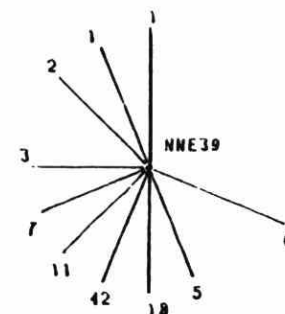
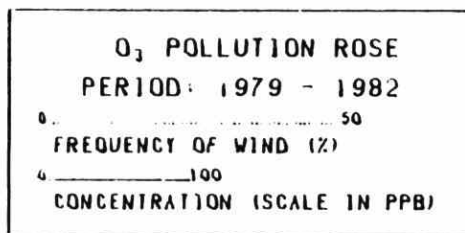
SUMMER

FALL

ANNUAL

EXCEEDANCES  
(calms not included)

Figure 27



WNW12  
 JARV15  
 (85% LEVEL)

WNW12  
 JARV15  
 (85% LEVEL)

WNW12  
 JARV15  
 (85% LEVEL)

WNW12  
 JARV15  
 (85% LEVEL)

WNW12  
 JARV15  
 (85% LEVEL)



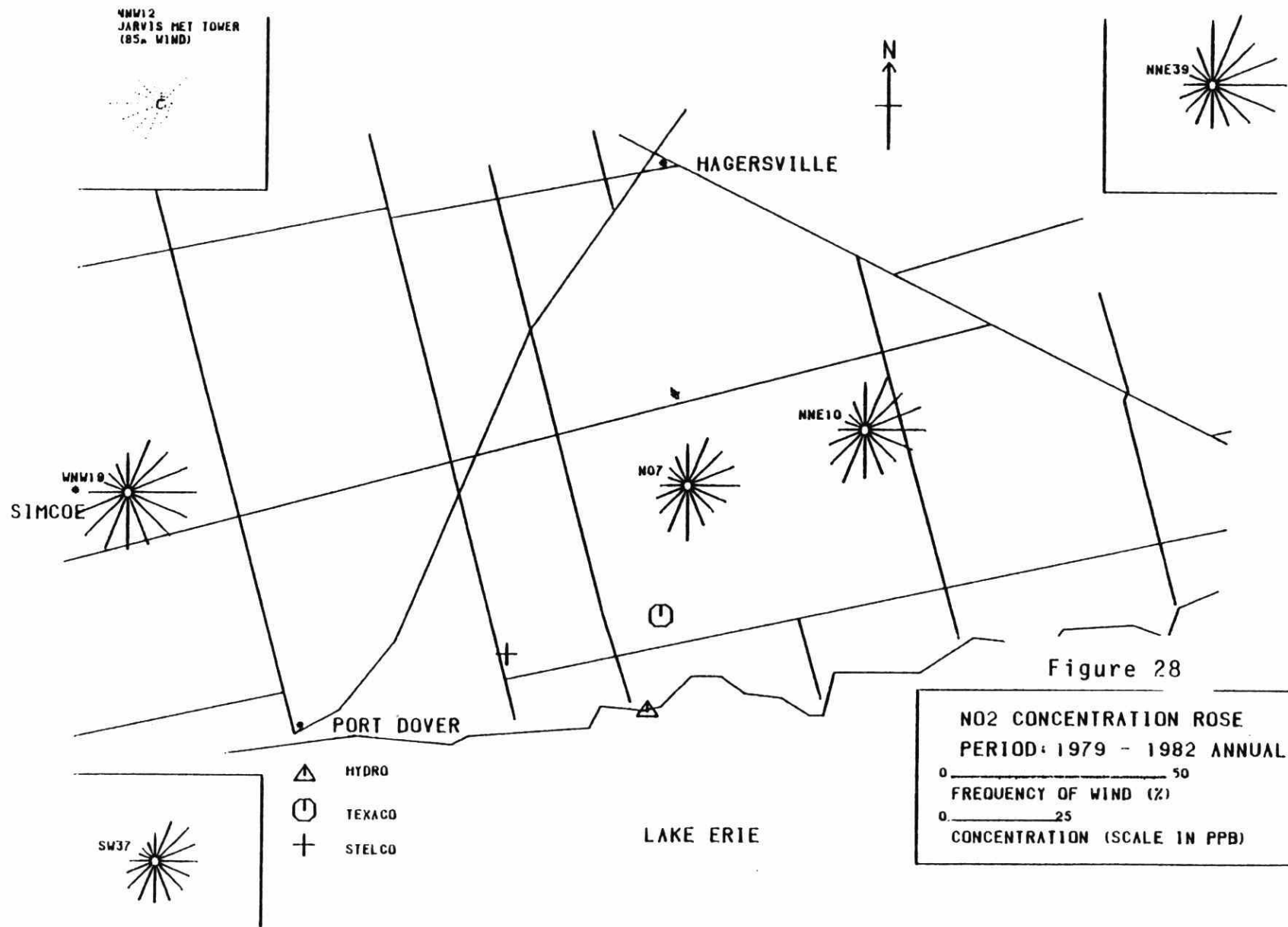
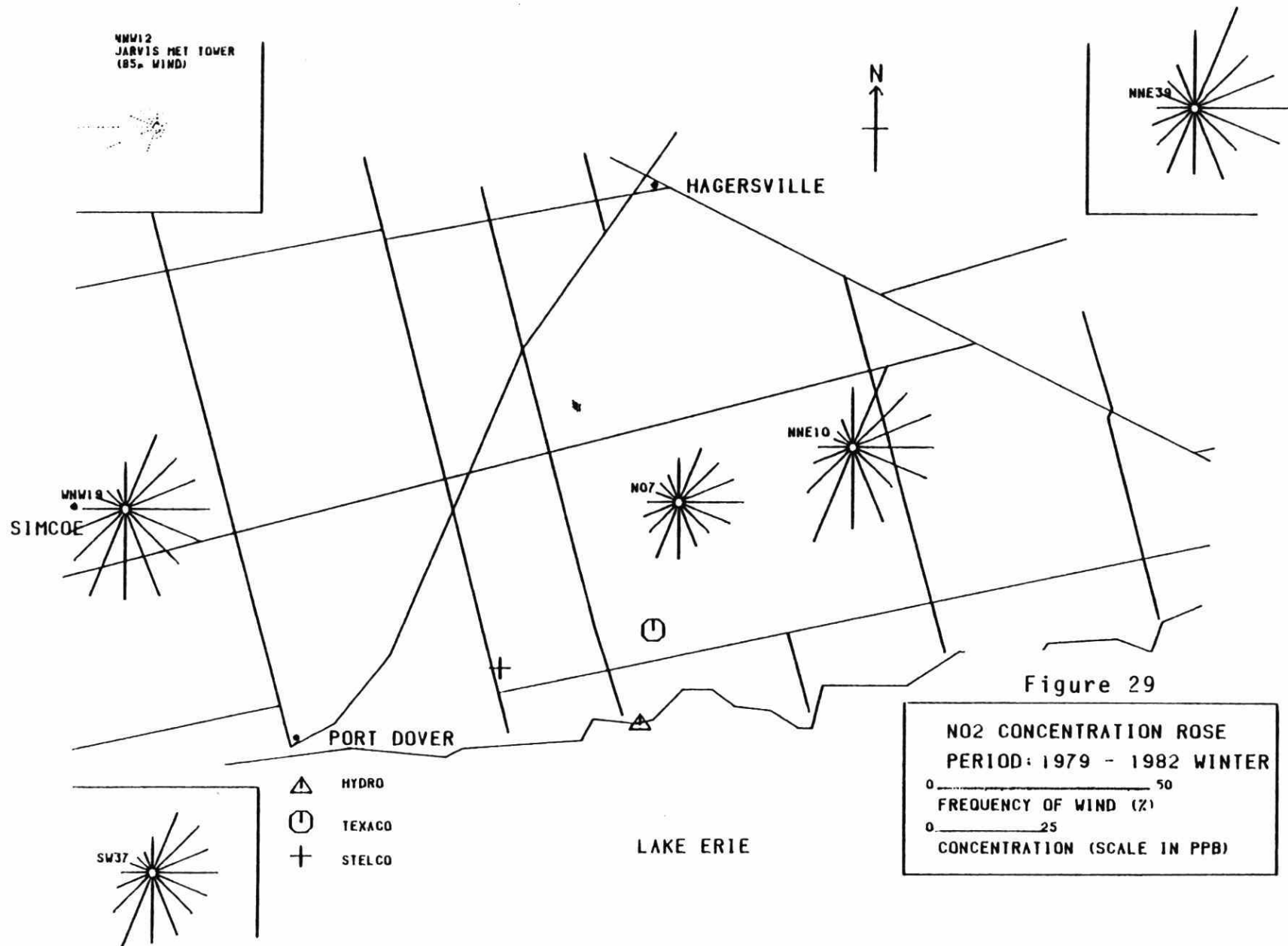
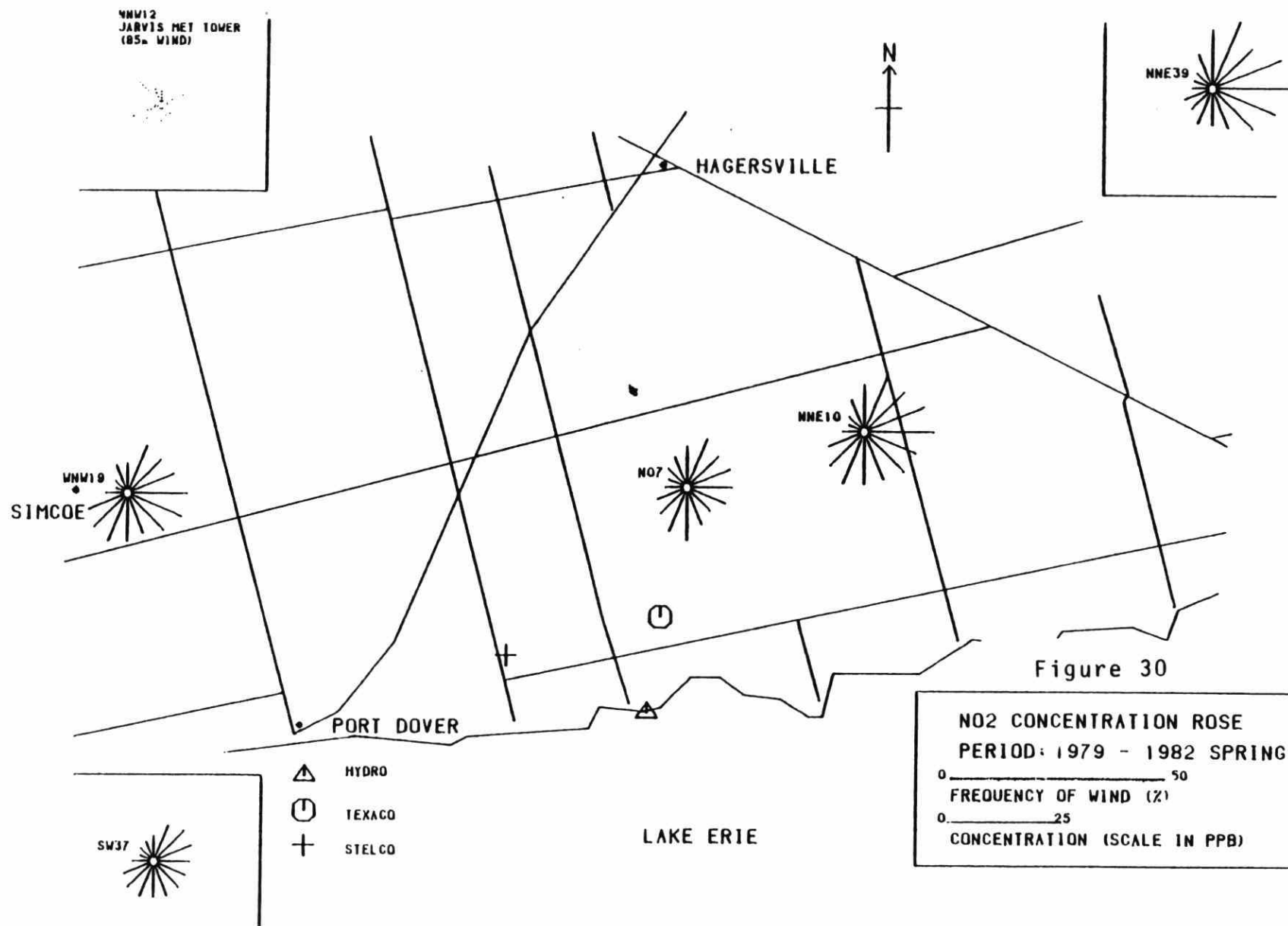
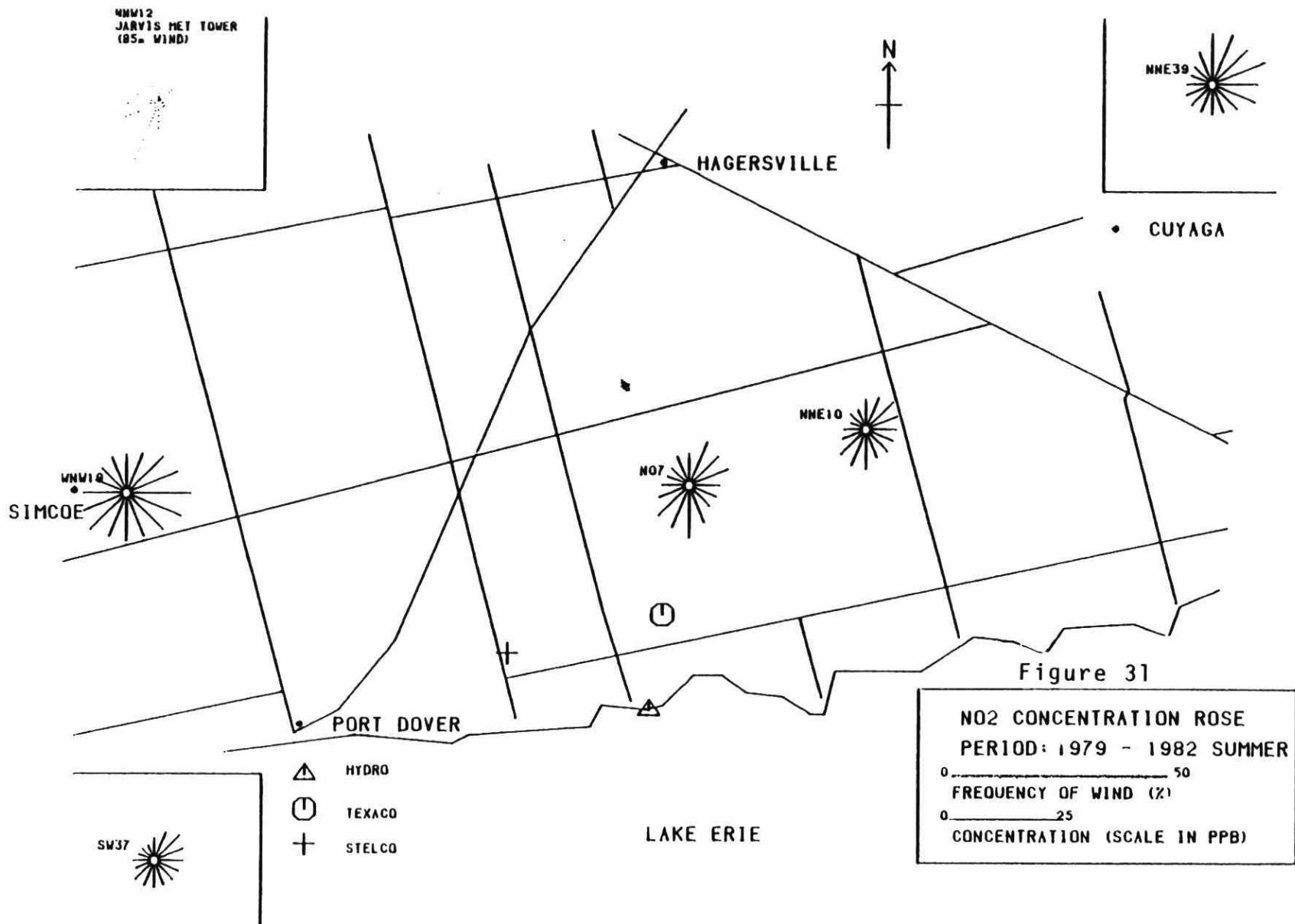
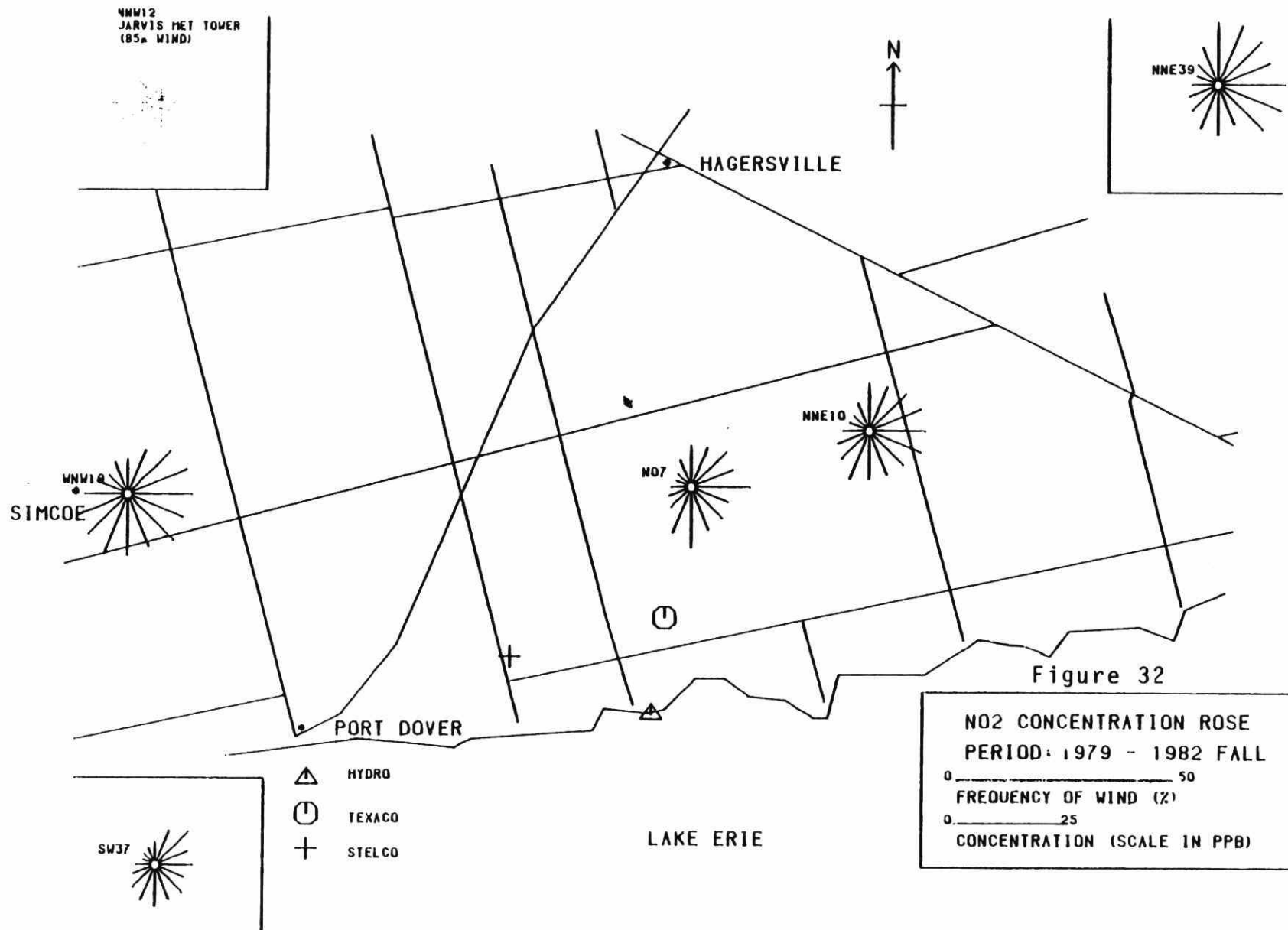


Figure 28









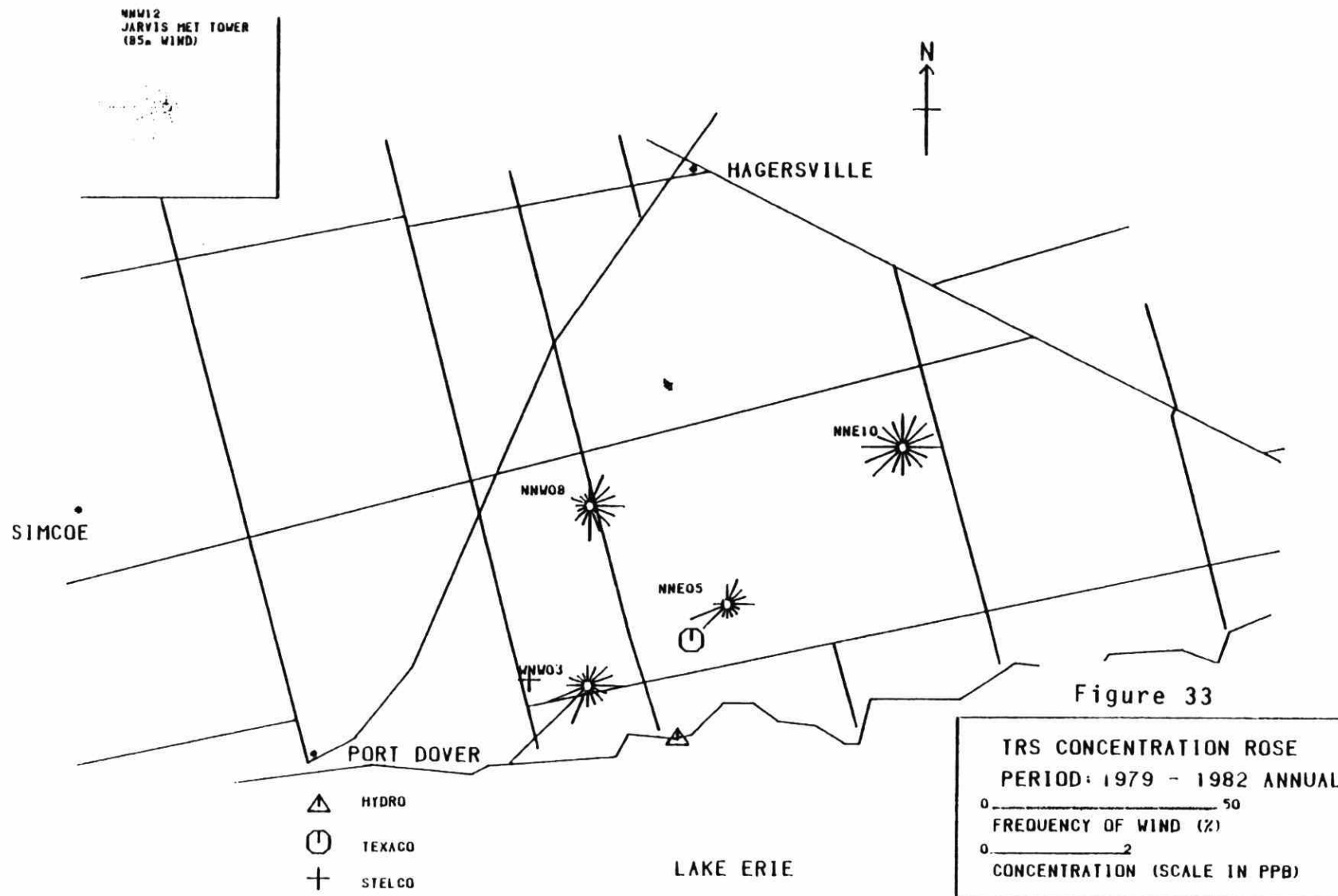
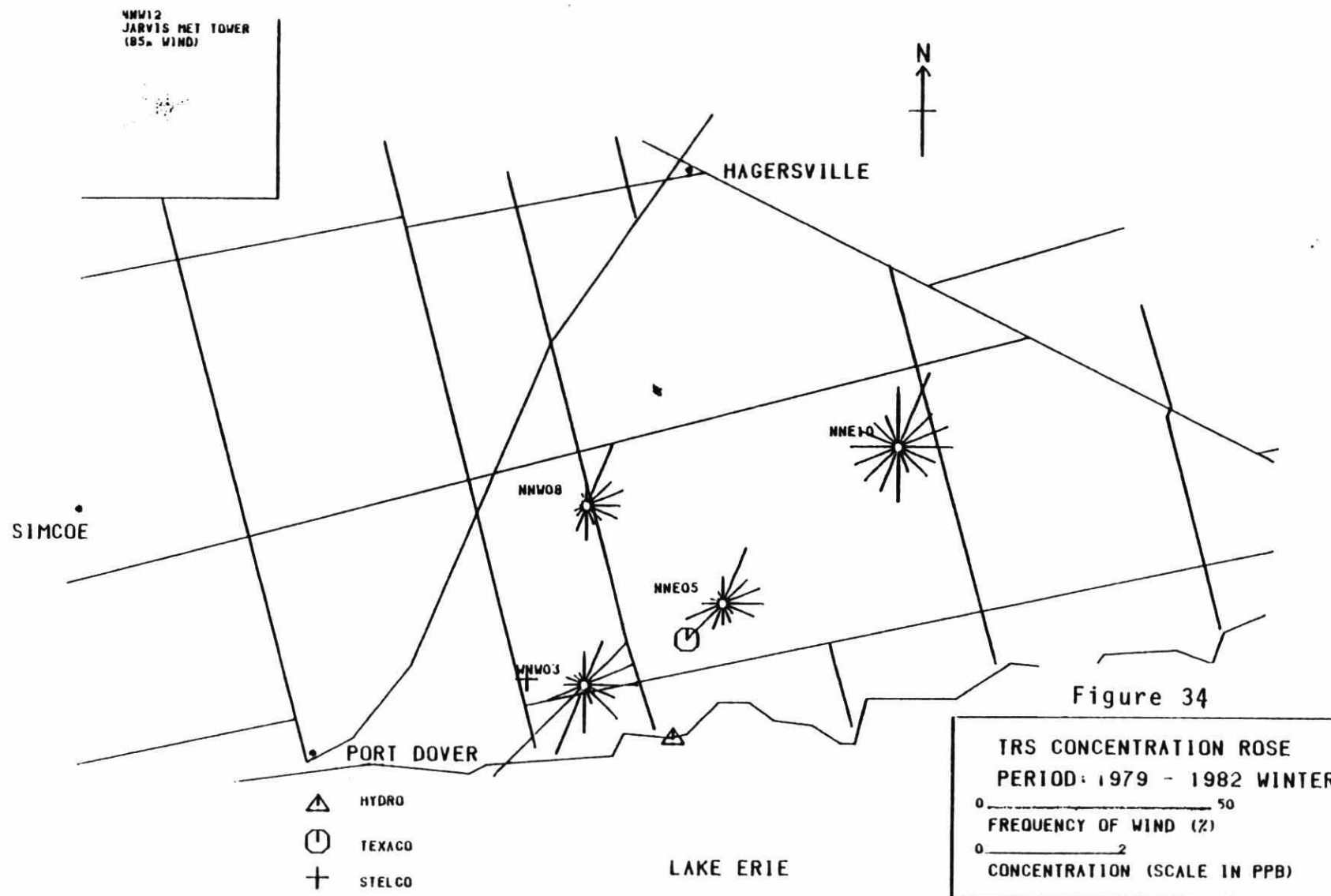
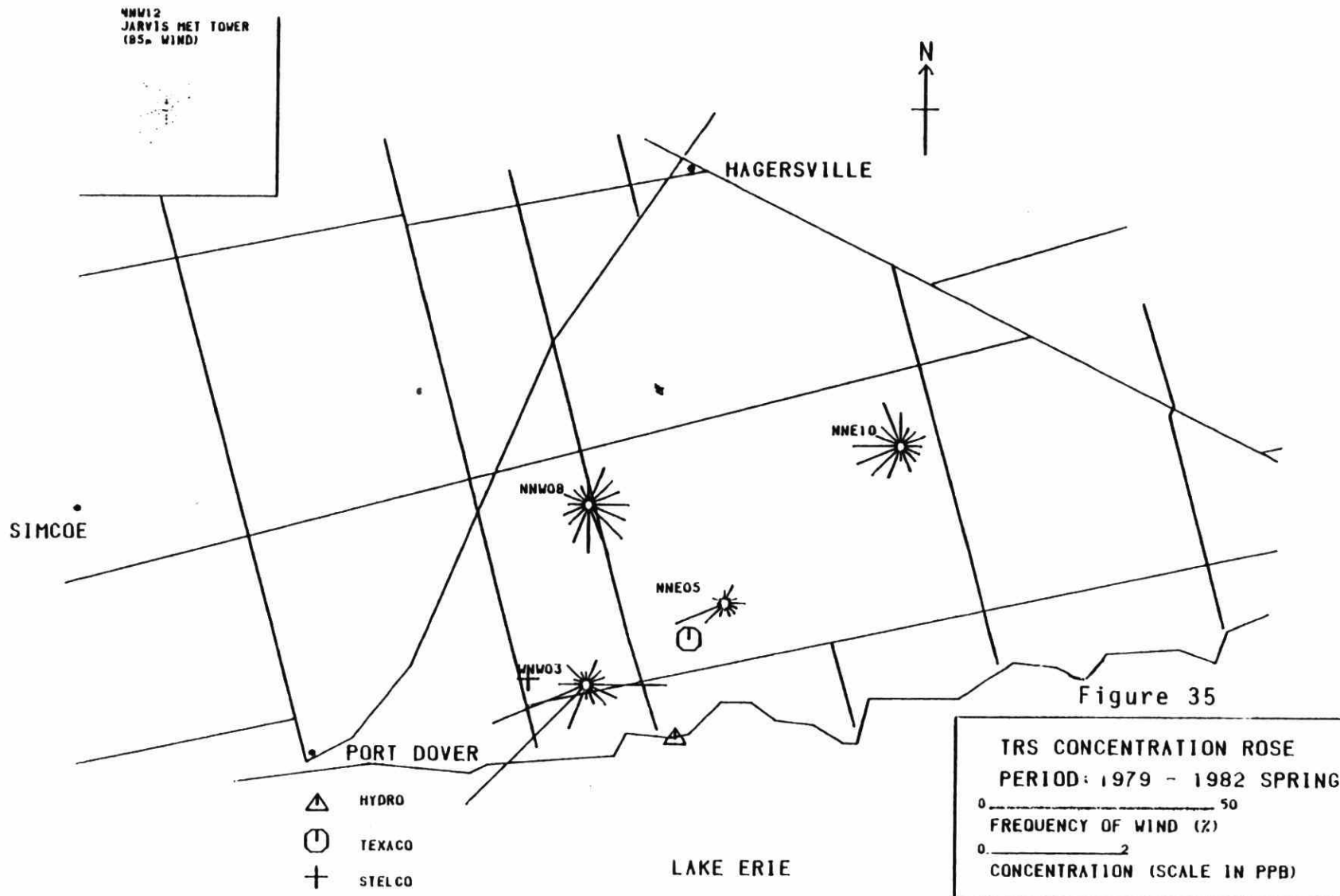
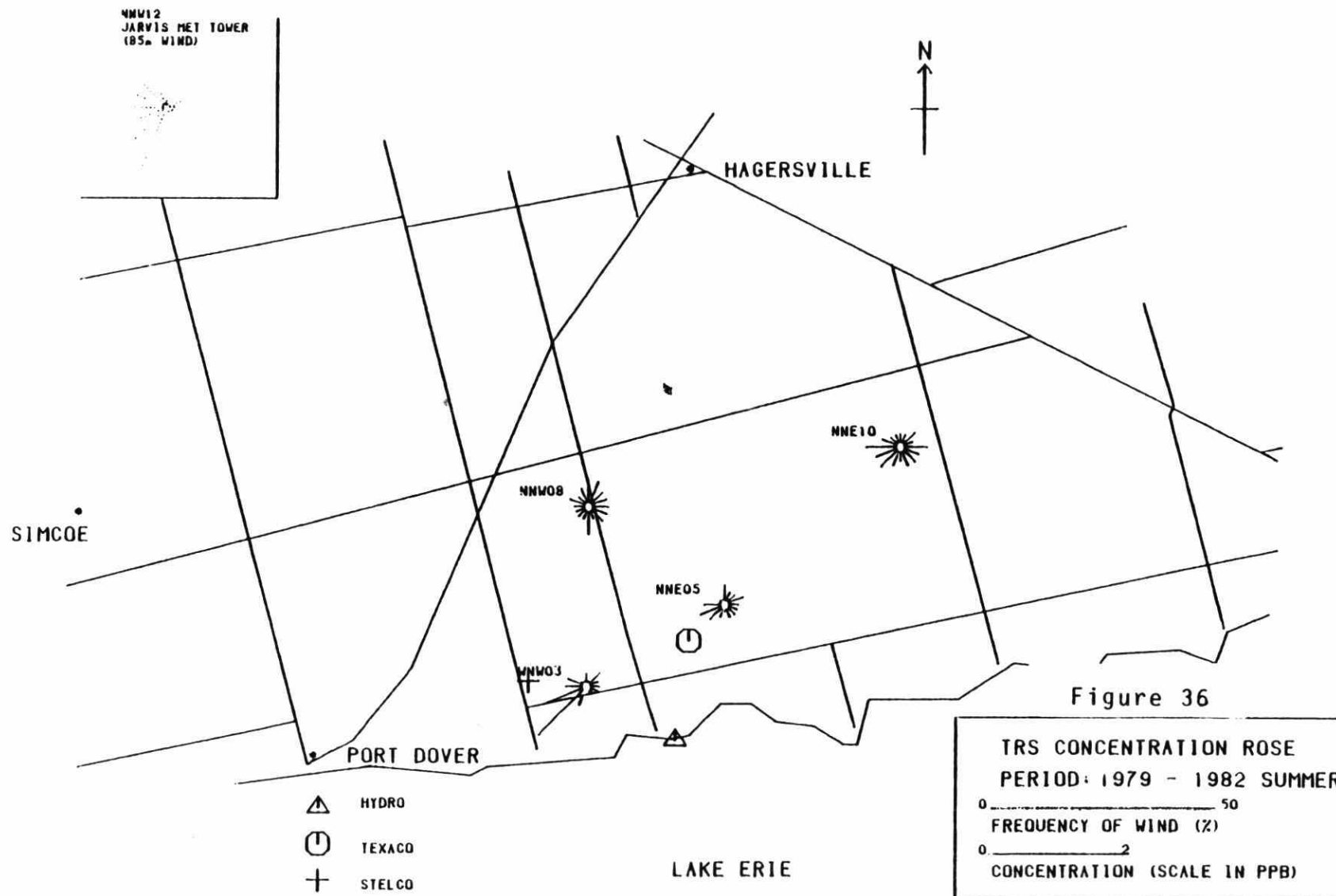


Figure 33









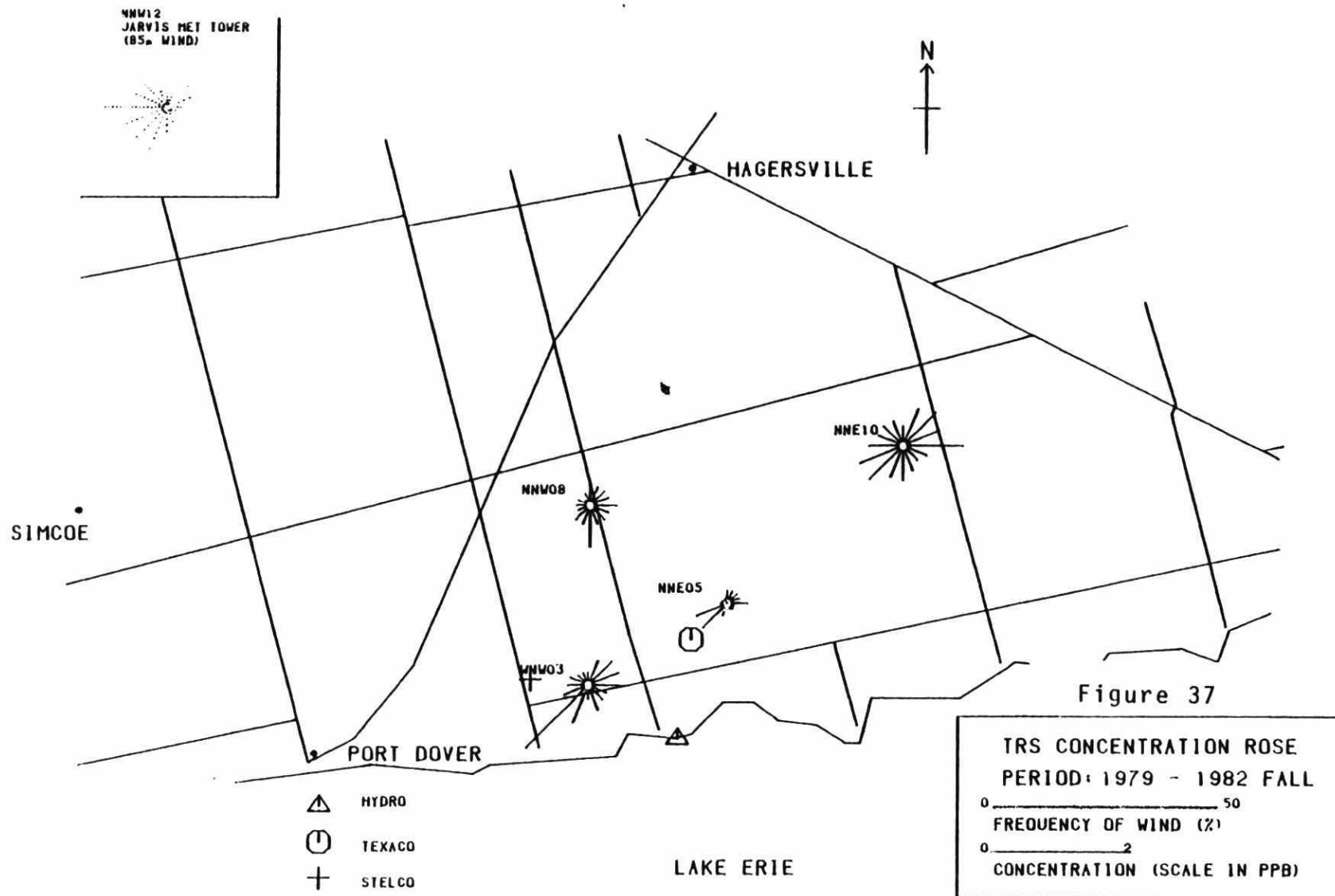
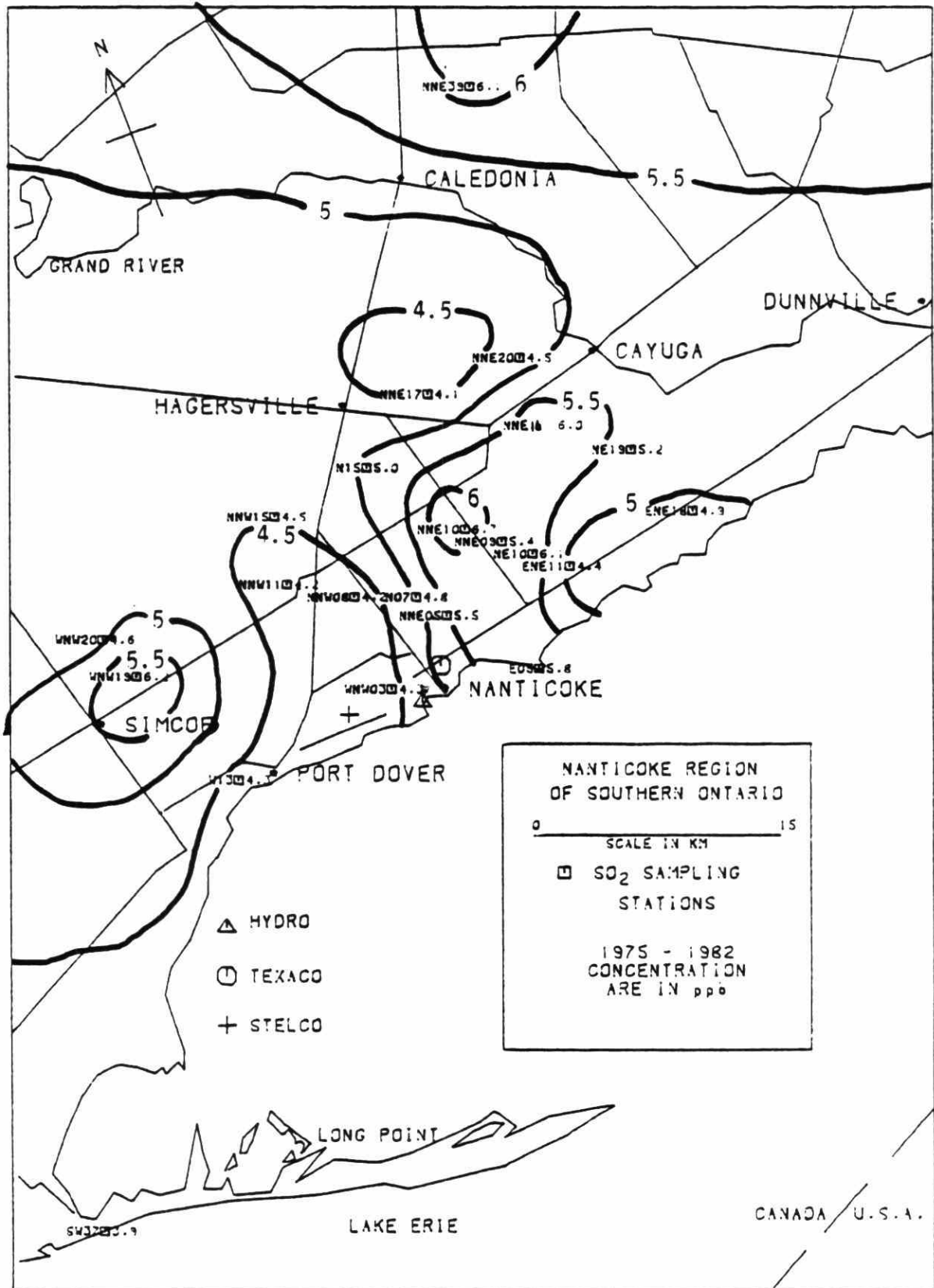
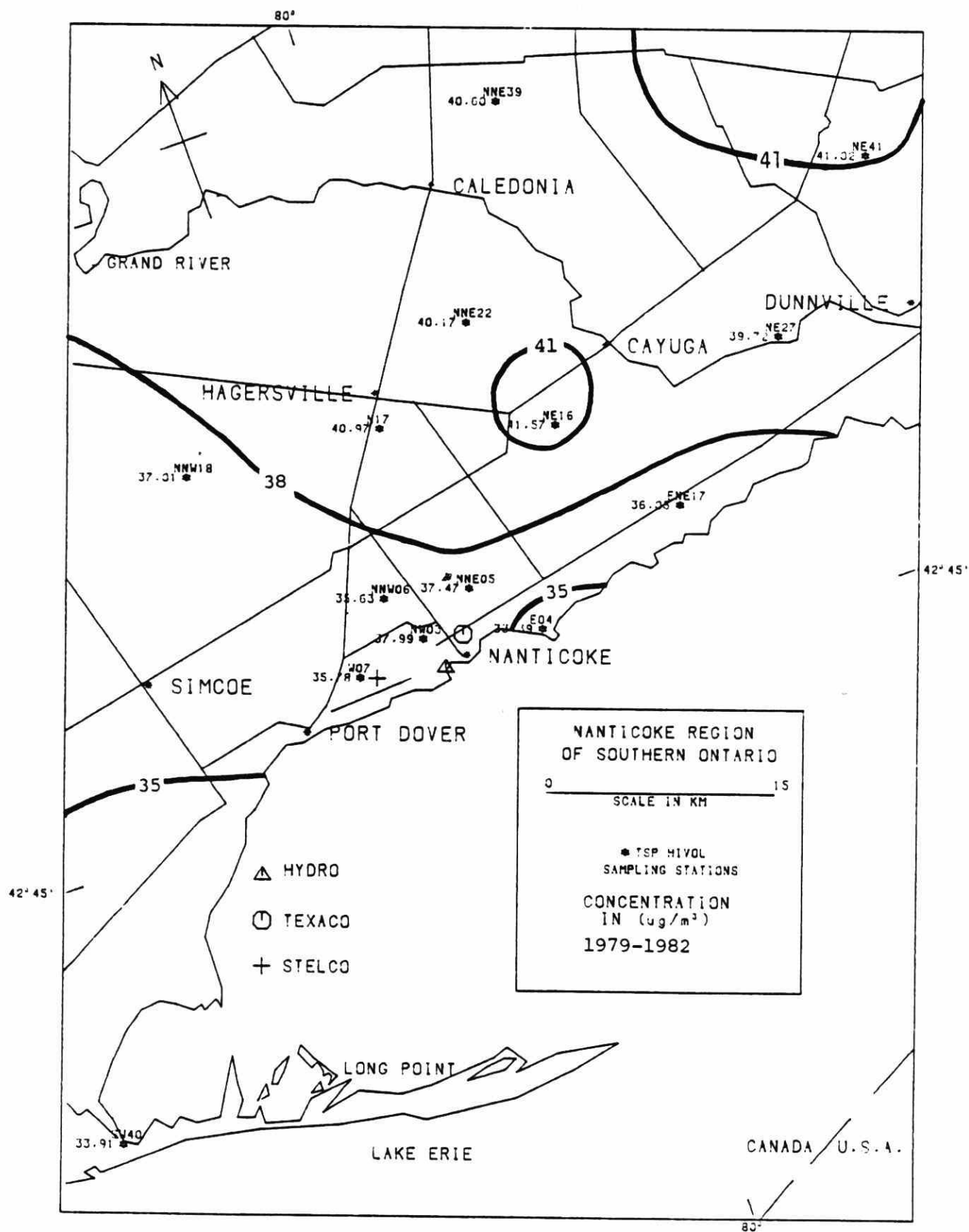


Figure 38  
Spatial Distribution of  $\text{SO}_2$  Concentrations





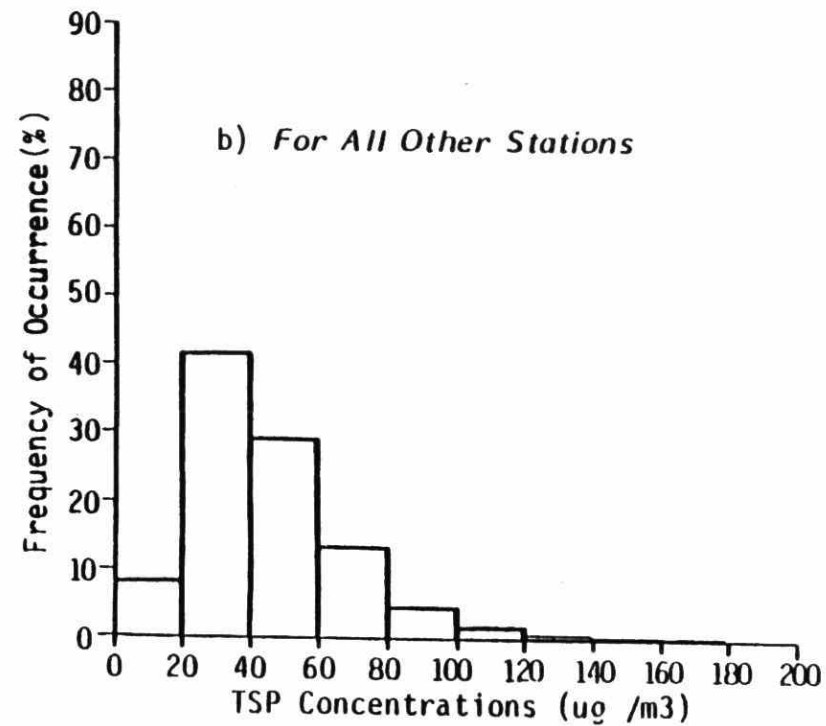
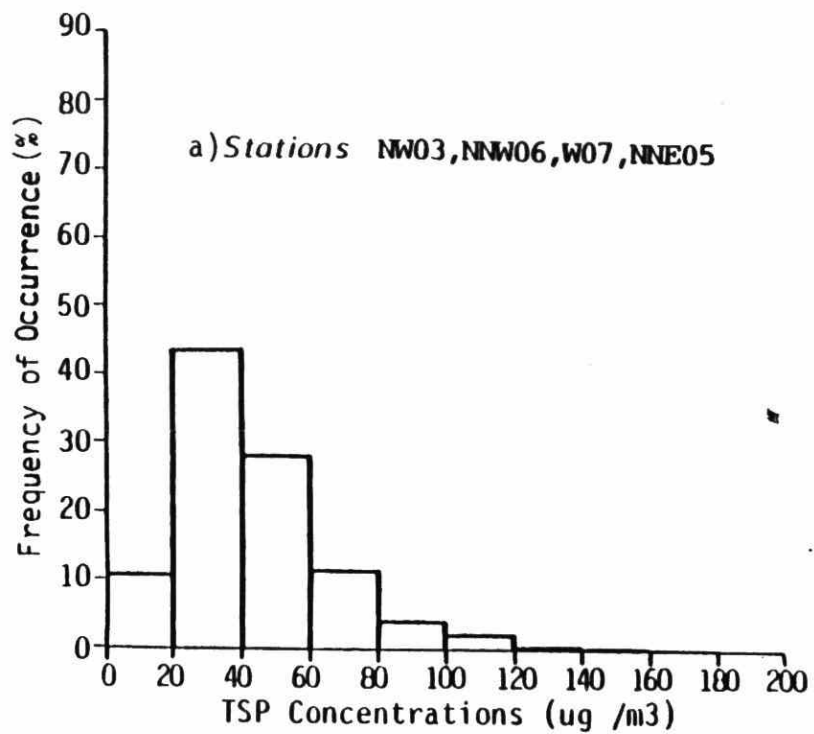


Figure 40

1979 - 1982 TSP FREQUENCY DISTRIBUTION  
ALL SEASONS

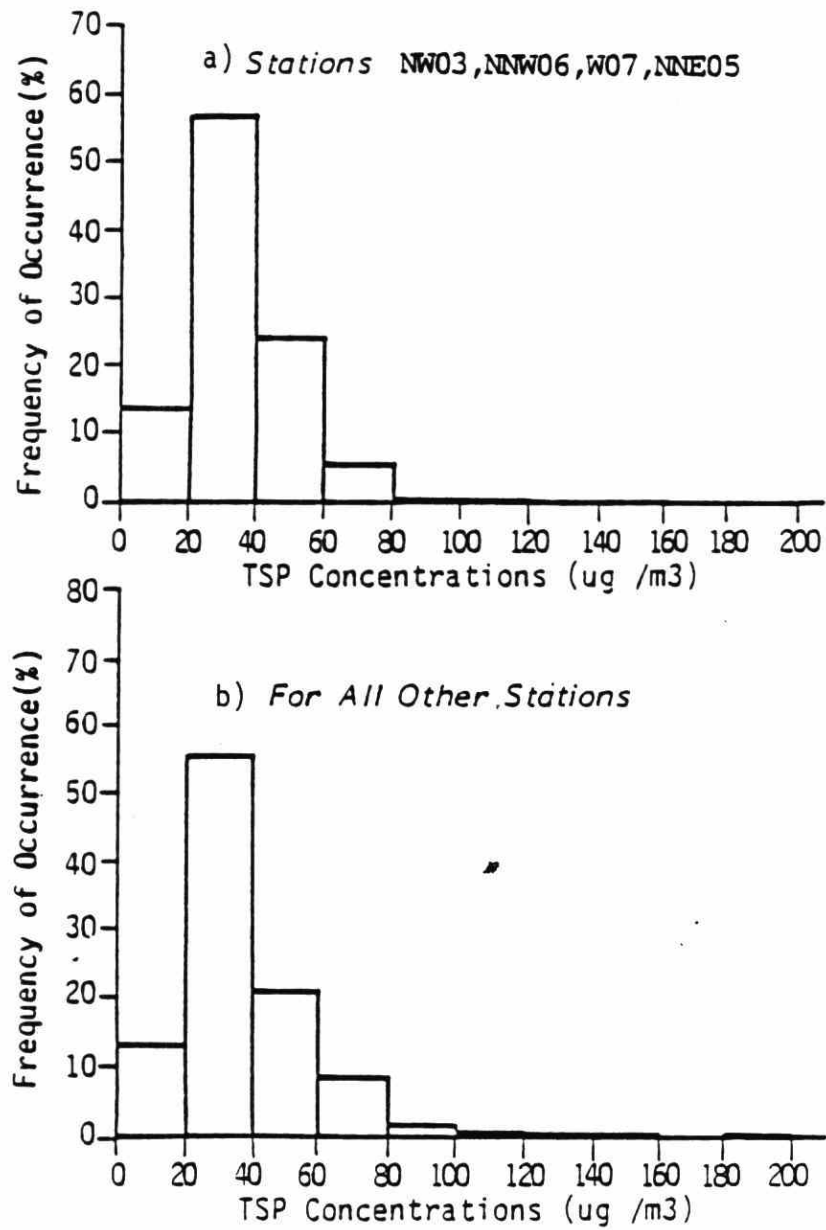
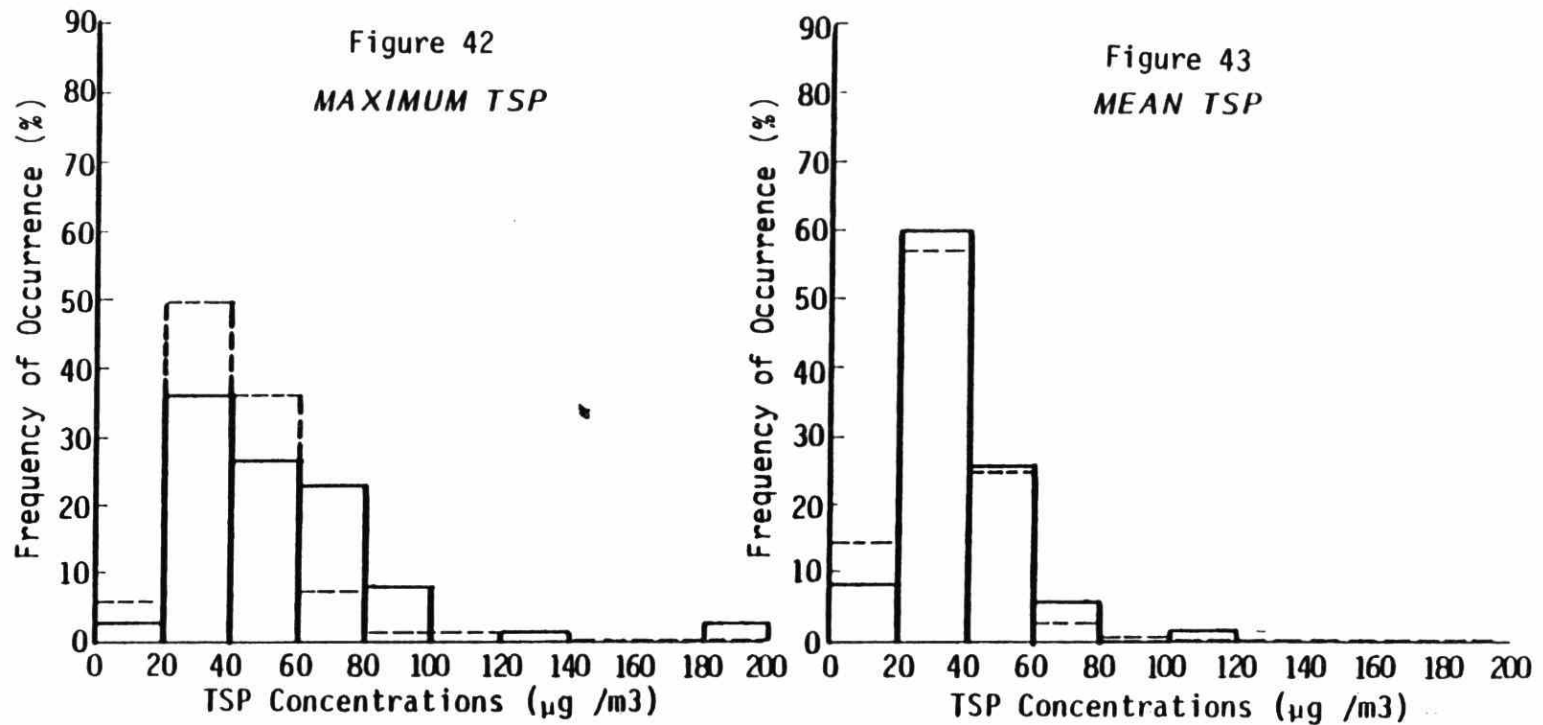


Figure 41  
1979-1982 TSP FREQUENCY DISTRIBUTION  
WINTER

WINTER TSP 1979-1982



Frequency Distributions

- Stations NW03, NNW06, W07, NNE05
- All Other Stations

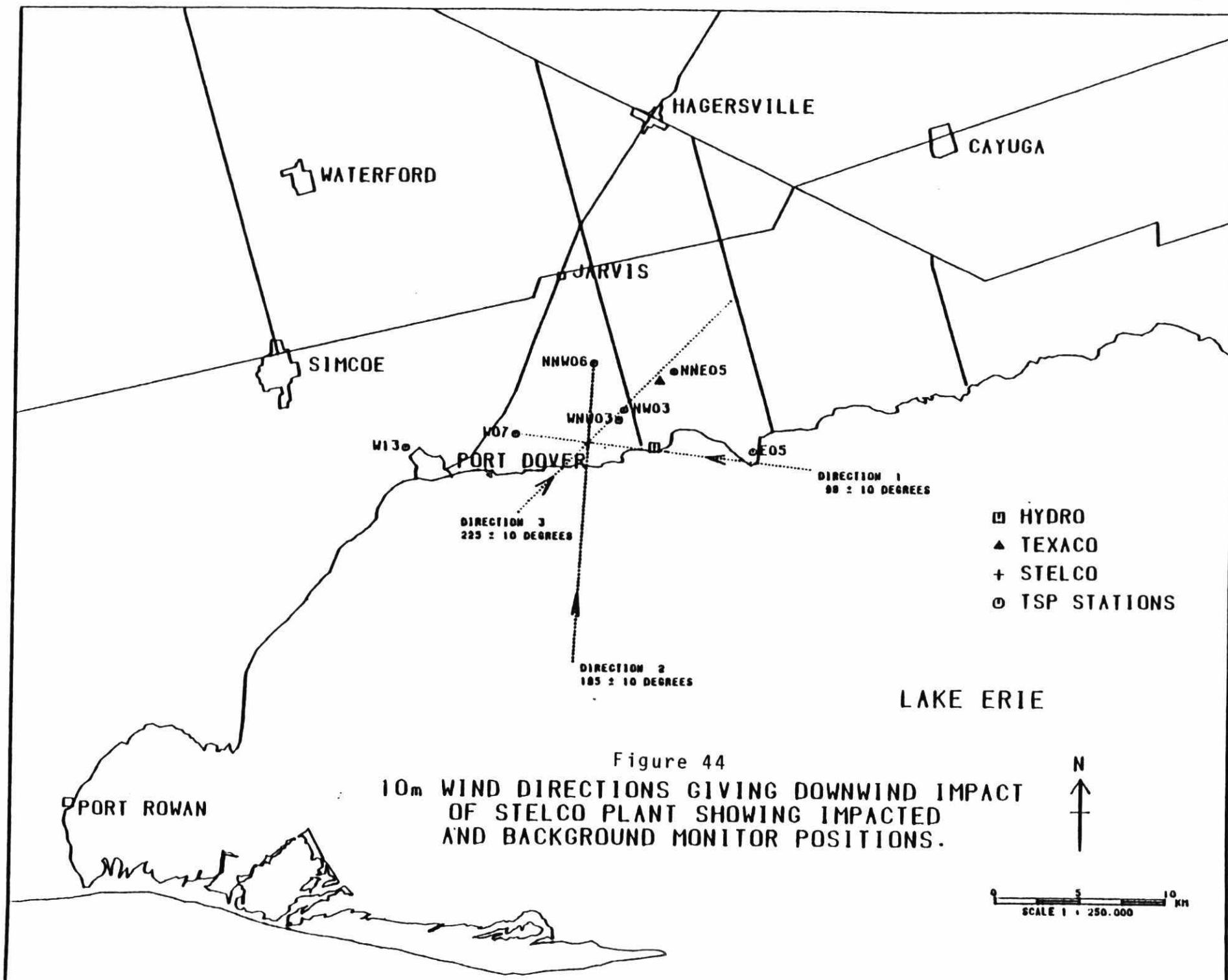
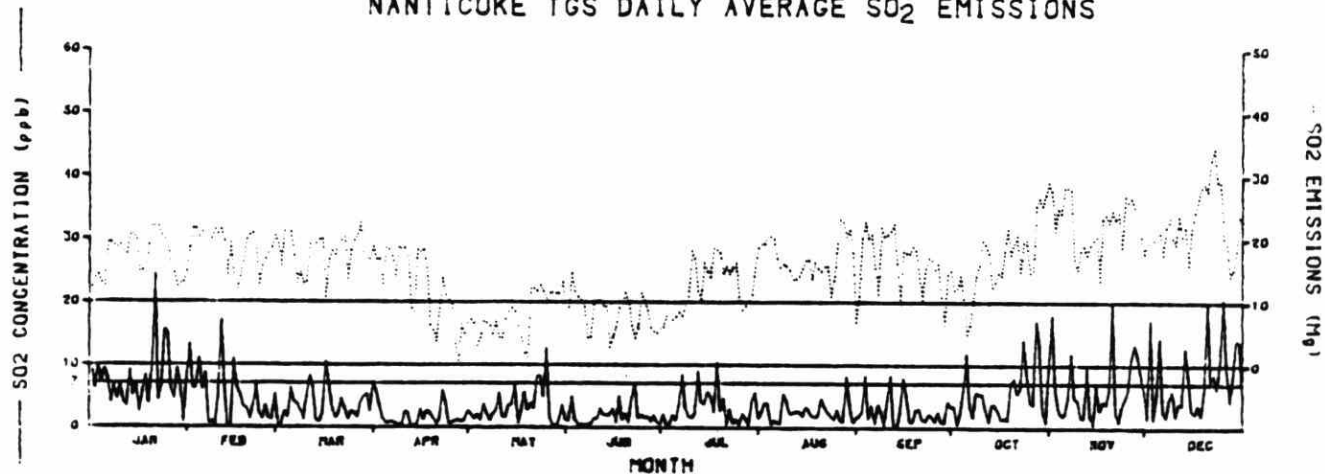




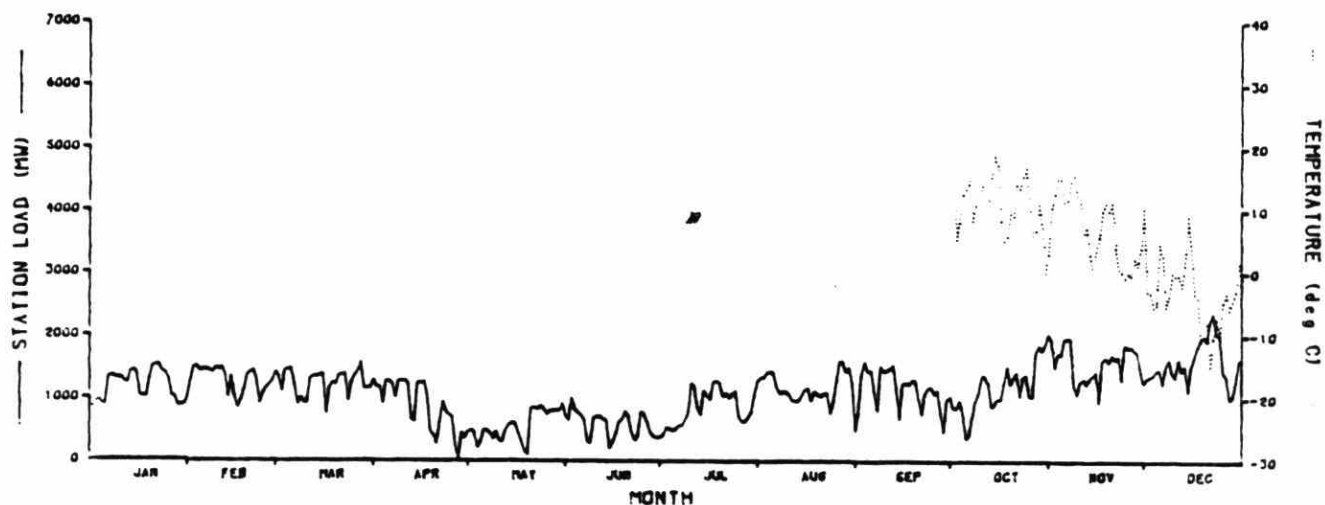
Figure 45

DAILY STATISTICS FOR THE SO<sub>2</sub> NETWORK 1975

a) DAILY NETWORK AVERAGE SO<sub>2</sub> CONCENTRATION AND  
NANTICOKE TGS DAILY AVERAGE SO<sub>2</sub> EMISSIONS



b) DAILY AVERAGE STATION LOAD AT NANTICOKE TGS AND DAILY  
AVERAGE AIR TEMPERATURE AT JARVIS MET TOWER



c) DAILY NETWORK MAXIMUM SO<sub>2</sub> CONCENTRATION AND  
NANTICOKE TGS SO<sub>2</sub> EMISSIONS AT THE MAXIMUM  
CONCENTRATION HOUR

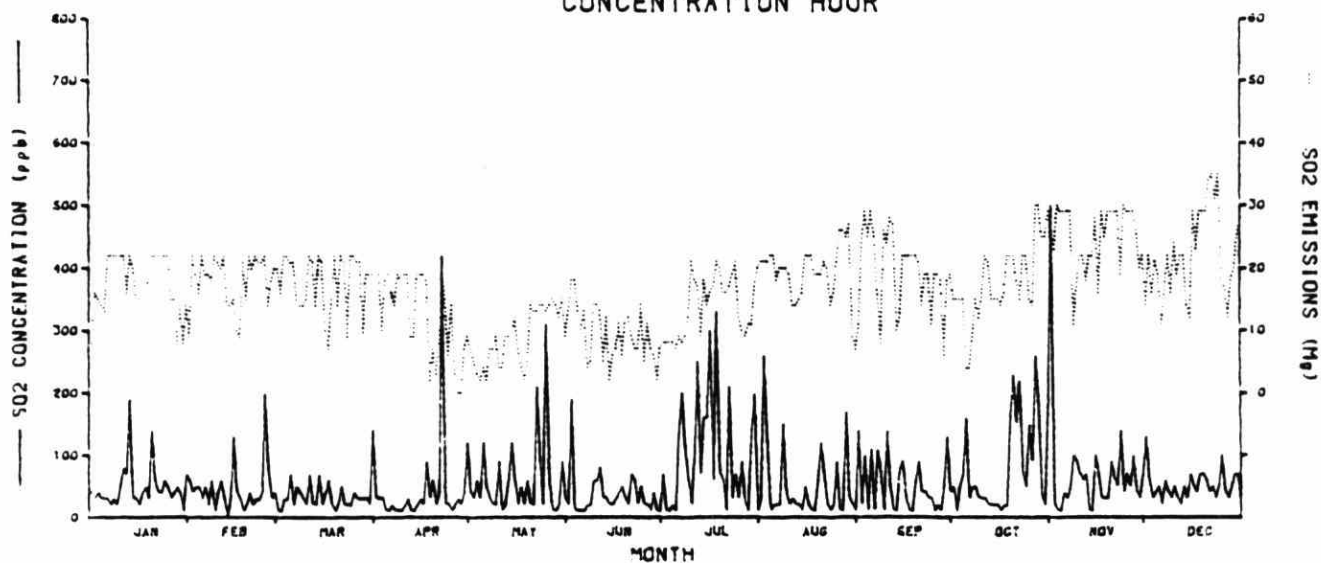
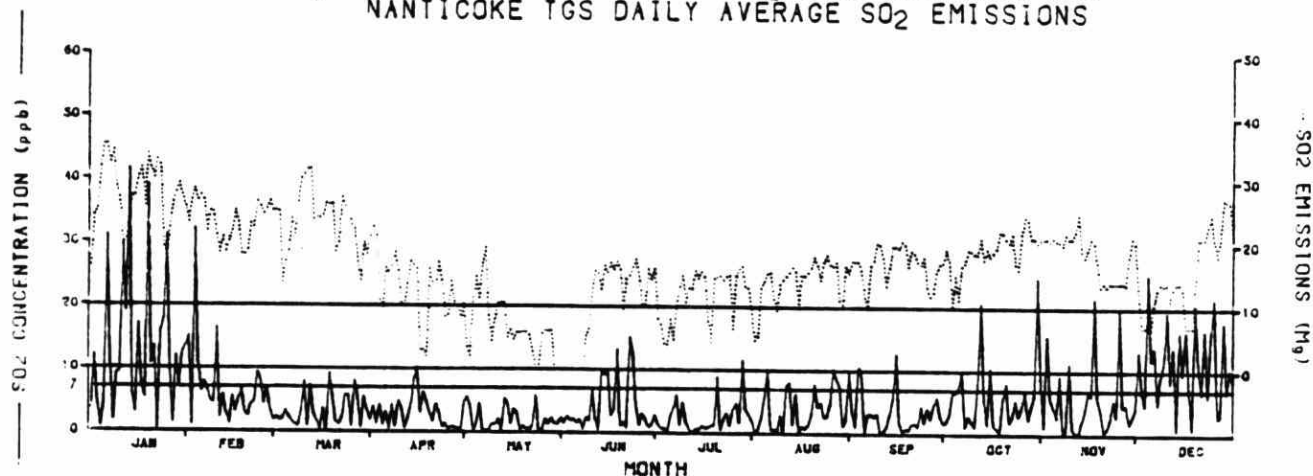
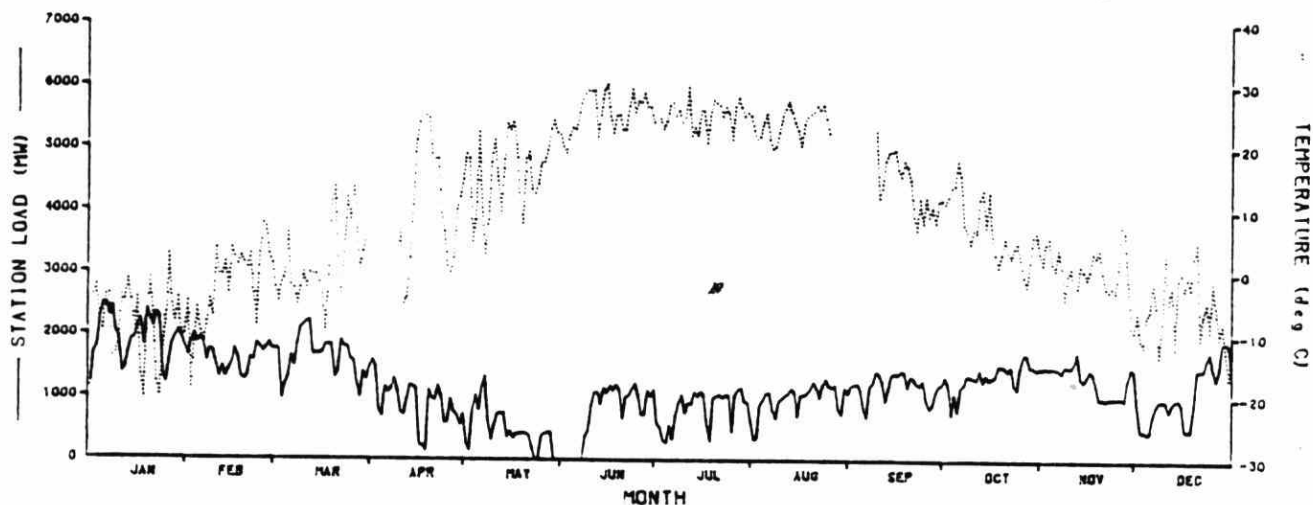


Figure 46  
DAILY STATISTICS FOR THE SO<sub>2</sub> NETWORK 1976

a) DAILY NETWORK AVERAGE SO<sub>2</sub> CONCENTRATION AND  
NANTICOKE TGS DAILY AVERAGE SO<sub>2</sub> EMISSIONS



b) DAILY AVERAGE STATION LOAD AT NANTICOKE TGS AND DAILY  
AVERAGE AIR TEMPERATURE AT JARVIS MET TOWER



c) DAILY NETWORK MAXIMUM SO<sub>2</sub> CONCENTRATION AND  
NANTICOKE TGS SO<sub>2</sub> EMISSIONS AT THE MAXIMUM  
CONCENTRATION HOUR

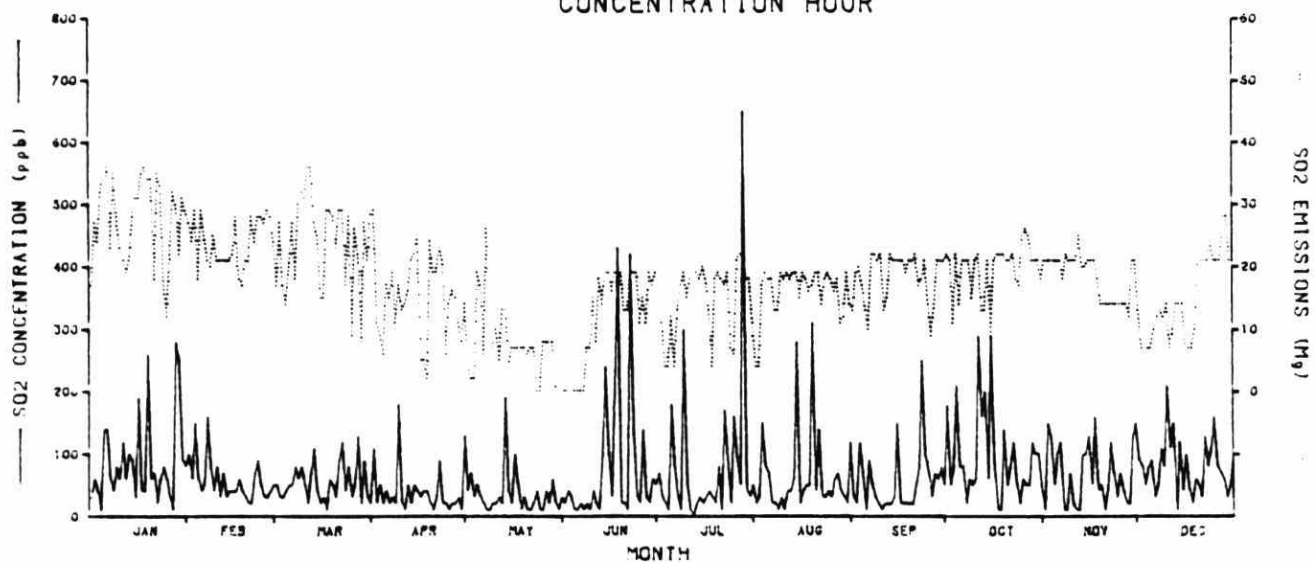
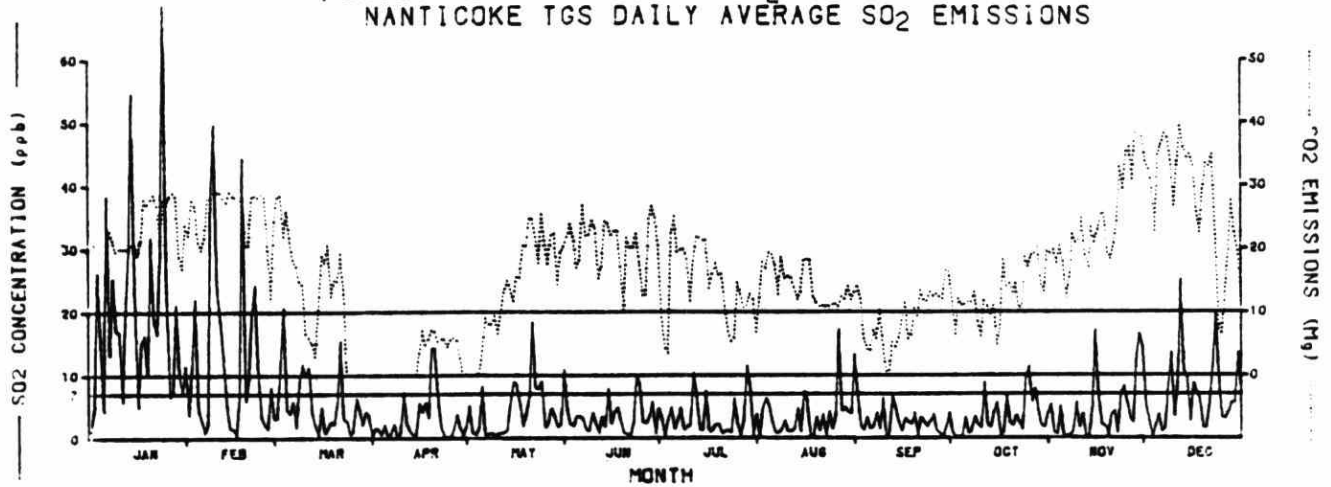


Figure 47

DAILY STATISTICS FOR THE SO<sub>2</sub> NETWORK 1977a) DAILY NETWORK AVERAGE SO<sub>2</sub> CONCENTRATION AND NANTICOKE TGS DAILY AVERAGE SO<sub>2</sub> EMISSIONS

b) DAILY AVERAGE STATION LOAD AT NANTICOKE TGS AND DAILY AVERAGE AIR TEMPERATURE AT JARVIS MET TOWER

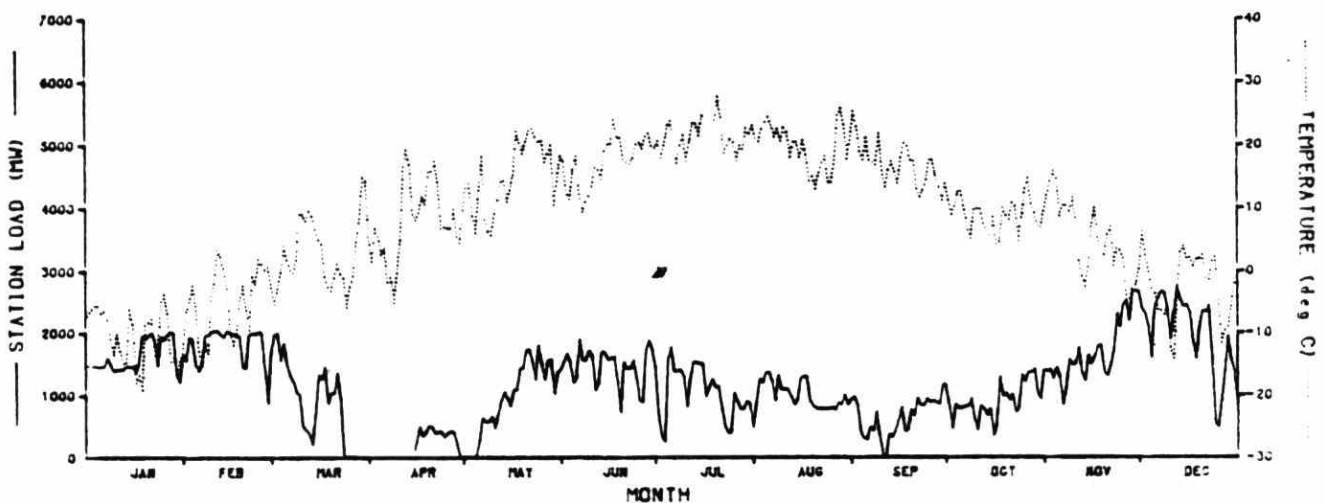
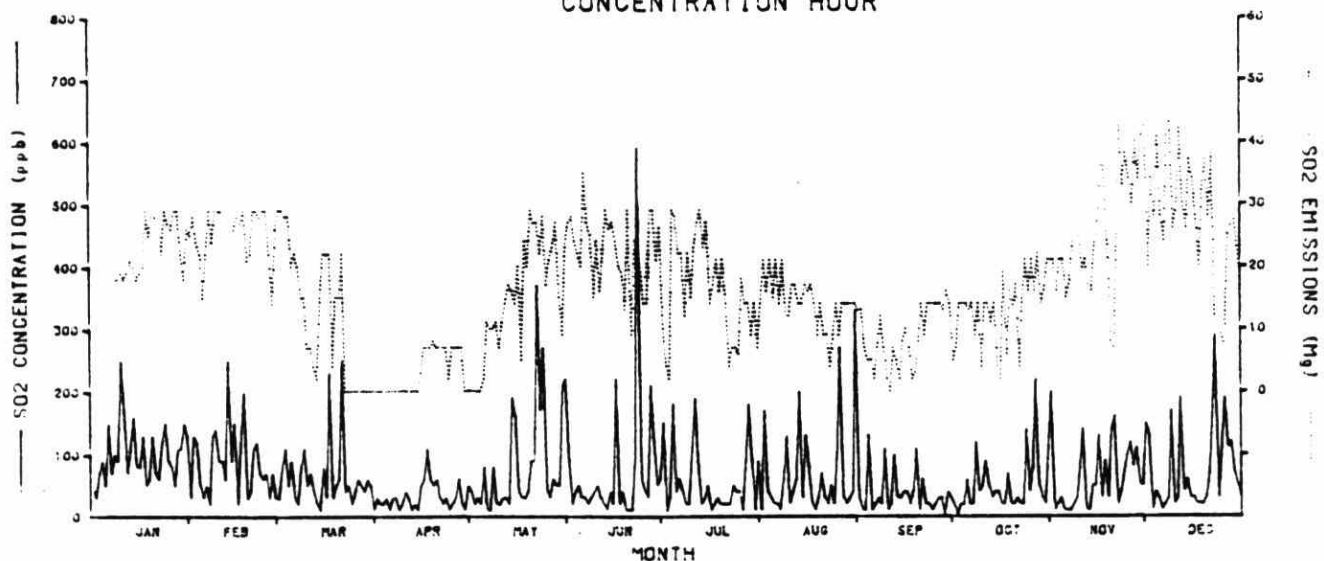
c) DAILY NETWORK MAXIMUM SO<sub>2</sub> CONCENTRATION AND NANTICOKE TGS SO<sub>2</sub> EMISSIONS AT THE MAXIMUM CONCENTRATION HOUR

Figure 48

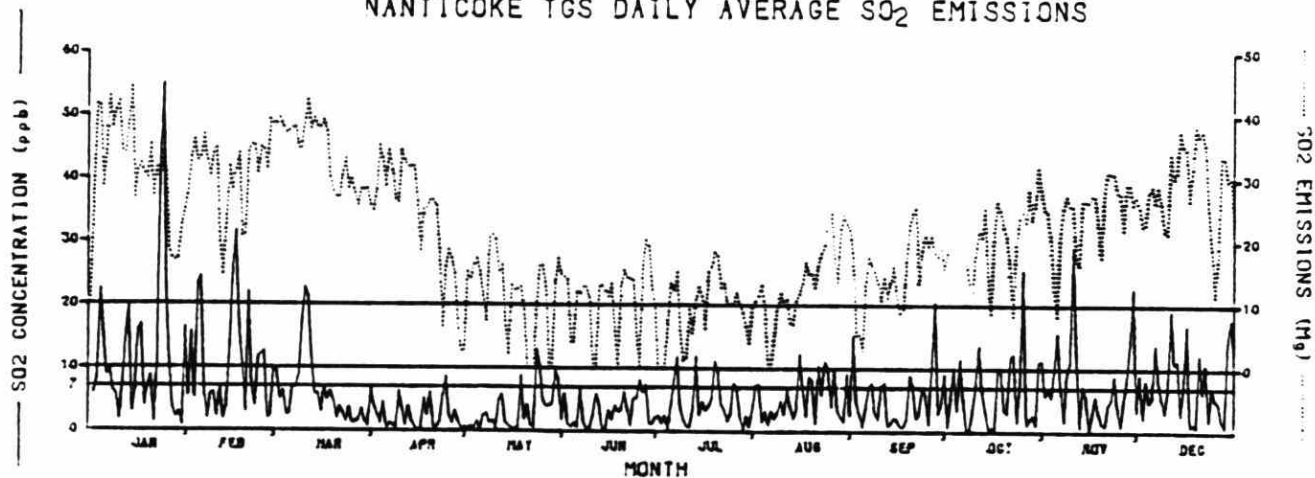
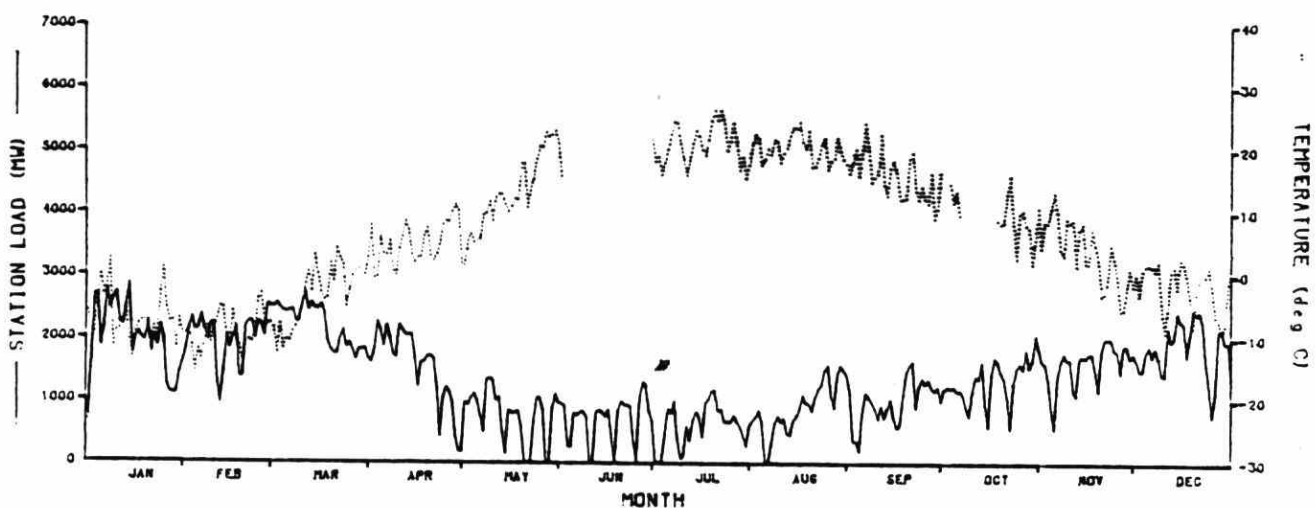
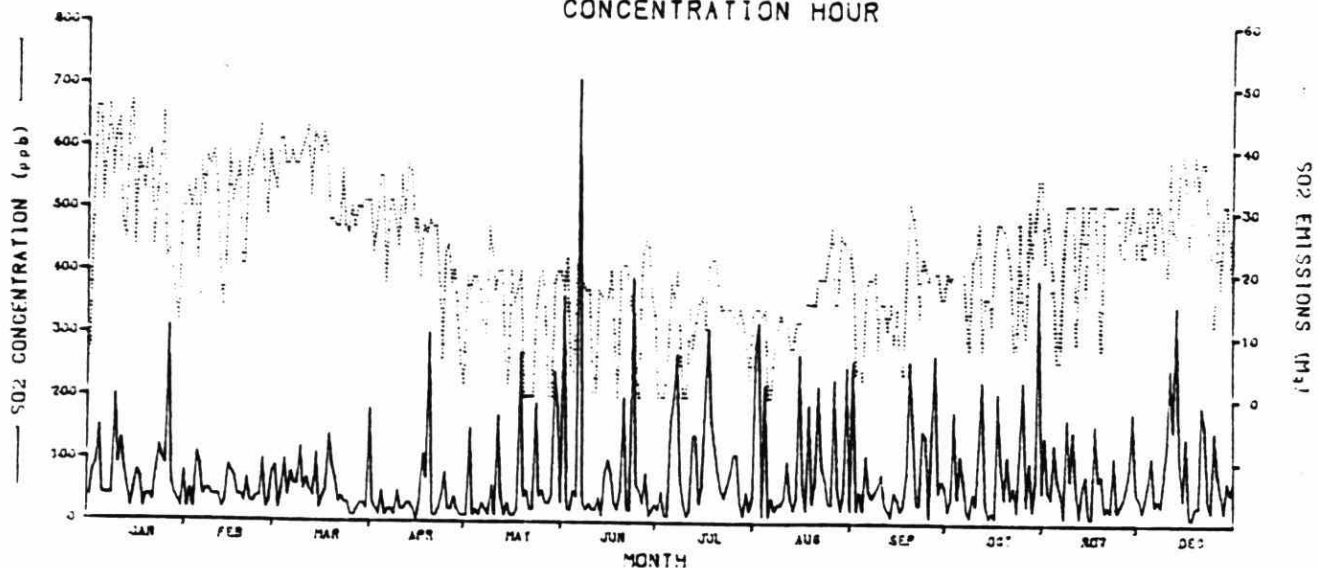
DAILY STATISTICS FOR THE SO<sub>2</sub> NETWORK 1978a) DAILY NETWORK AVERAGE SO<sub>2</sub> CONCENTRATION AND  
NANTICOKE TGS DAILY AVERAGE SO<sub>2</sub> EMISSIONSb) DAILY AVERAGE STATION LOAD AT NANTICOKE TGS AND DAILY  
AVERAGE AIR TEMPERATURE AT JARVIS MET TOWERc) DAILY NETWORK MAXIMUM SO<sub>2</sub> CONCENTRATION AND  
NANTICOKE TGS SO<sub>2</sub> EMISSIONS AT THE MAXIMUM  
CONCENTRATION HOUR

Figure 49

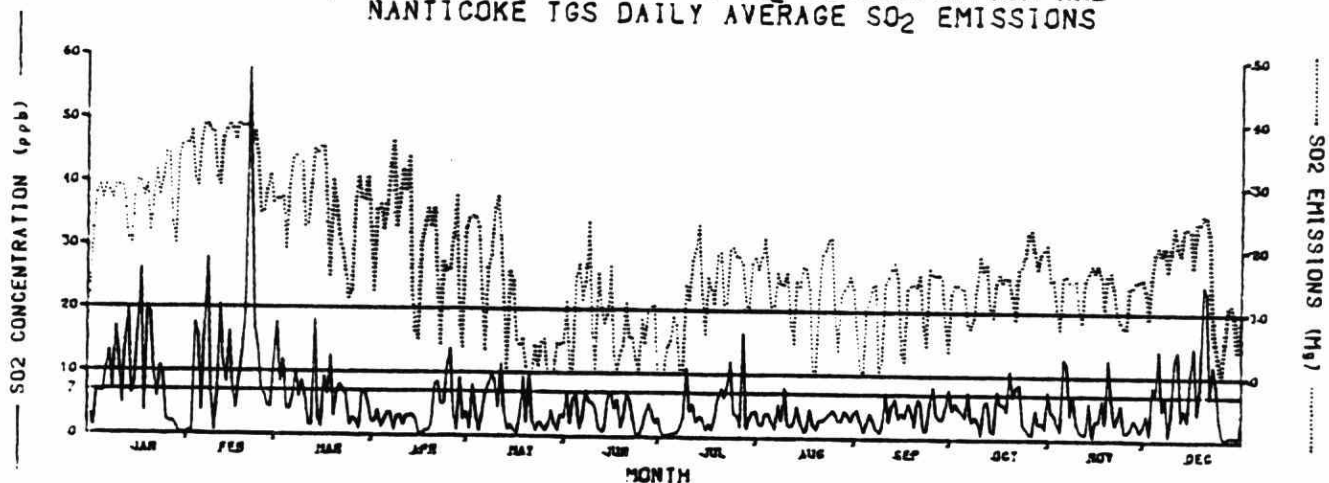
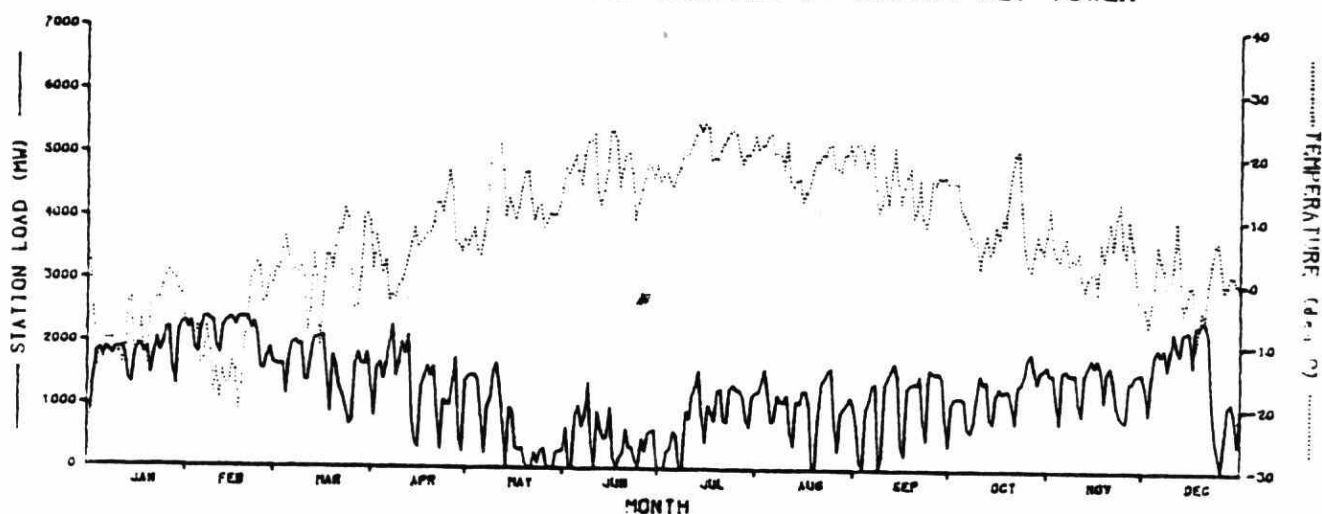
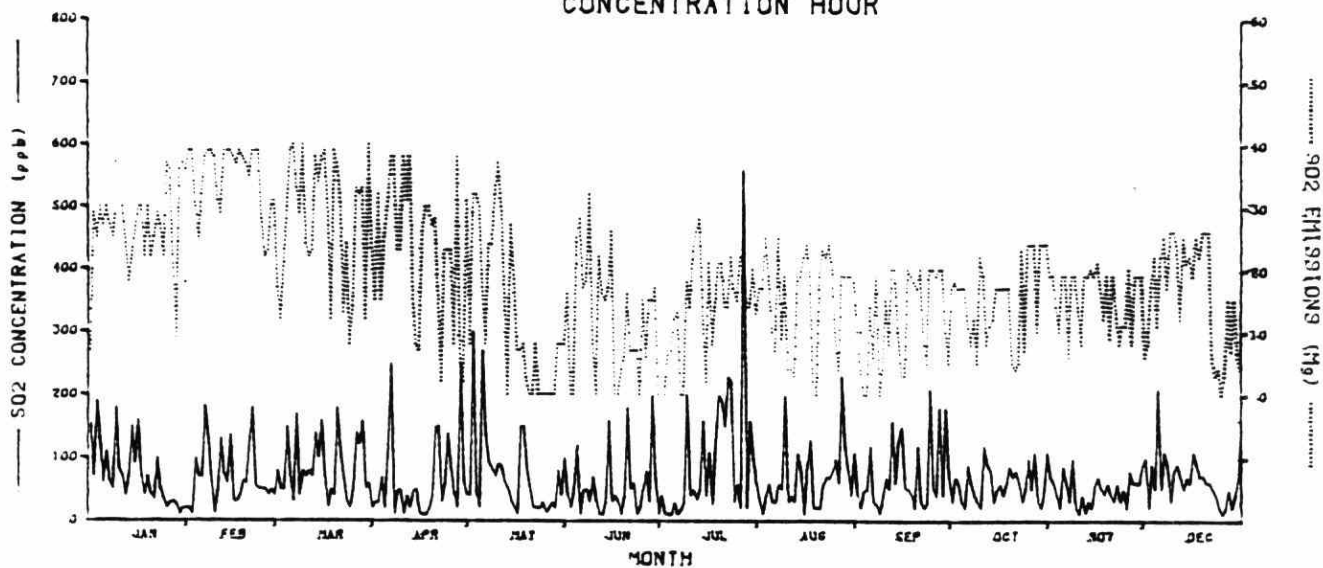
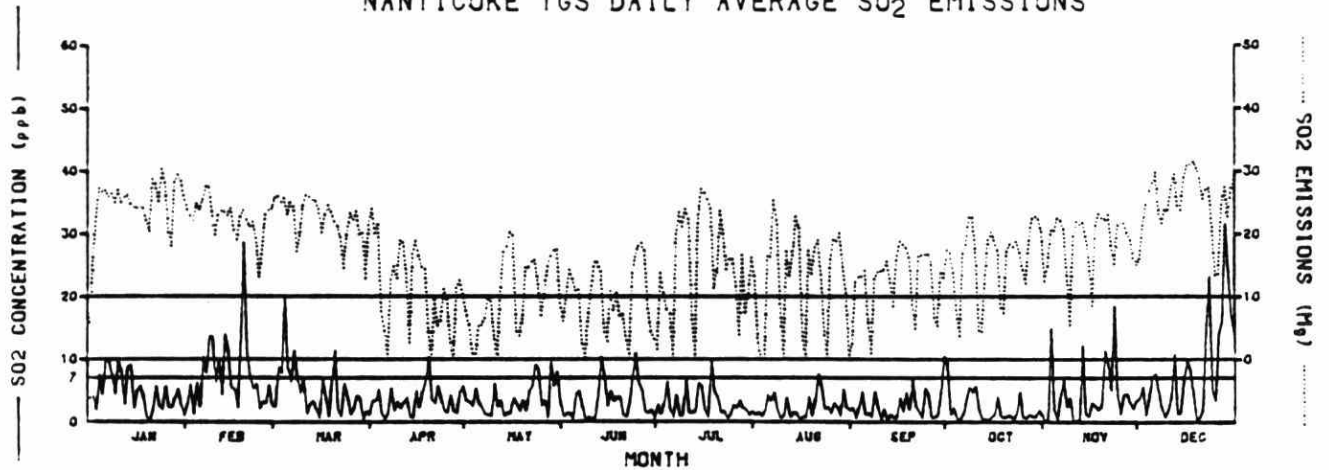
DAILY STATISTICS FOR THE SO<sub>2</sub> NETWORK 1979a) DAILY NETWORK AVERAGE SO<sub>2</sub> CONCENTRATION AND  
NANTICOKE TGS DAILY AVERAGE SO<sub>2</sub> EMISSIONSb) DAILY AVERAGE STATION LOAD AT NANTICOKE TGS AND DAILY  
AVERAGE AIR TEMPERATURE AT JARVIS MET TOWERc) DAILY NETWORK MAXIMUM SO<sub>2</sub> CONCENTRATION AND  
NANTICOKE TGS SO<sub>2</sub> EMISSIONS AT THE MAXIMUM  
CONCENTRATION HOUR

Figure 50

DAILY STATISTICS FOR THE SO<sub>2</sub> NETWORK 1980a) DAILY NETWORK AVERAGE SO<sub>2</sub> CONCENTRATION AND NANTICOKE TGS DAILY AVERAGE SO<sub>2</sub> EMISSIONS

b) DAILY AVERAGE STATION LOAD AT NANTICOKE TGS AND DAILY AVERAGE AIR TEMPERATURE AT JARVIS MET TOWER

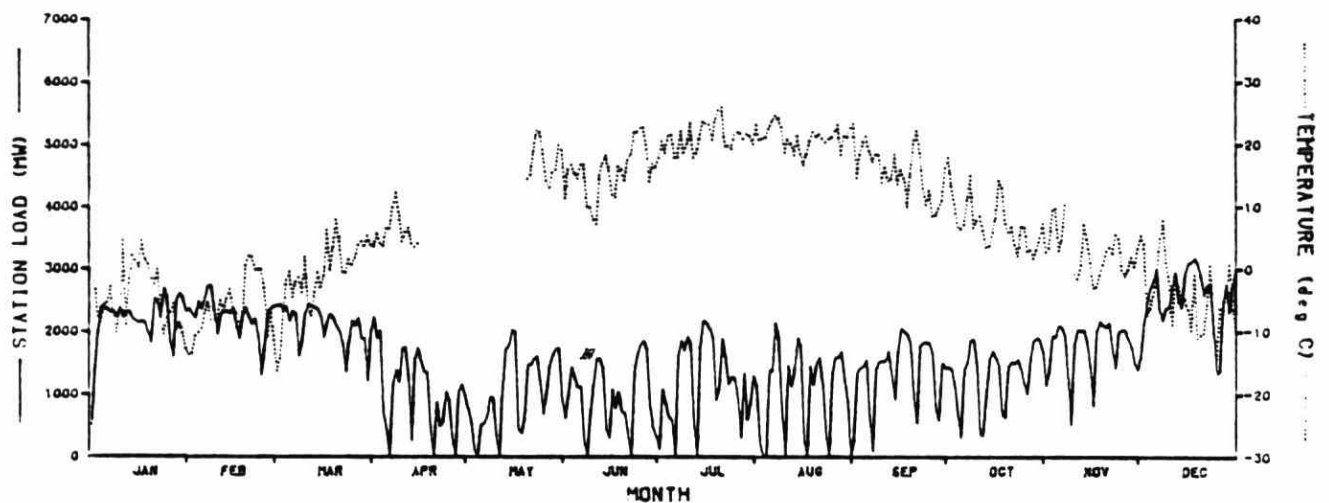
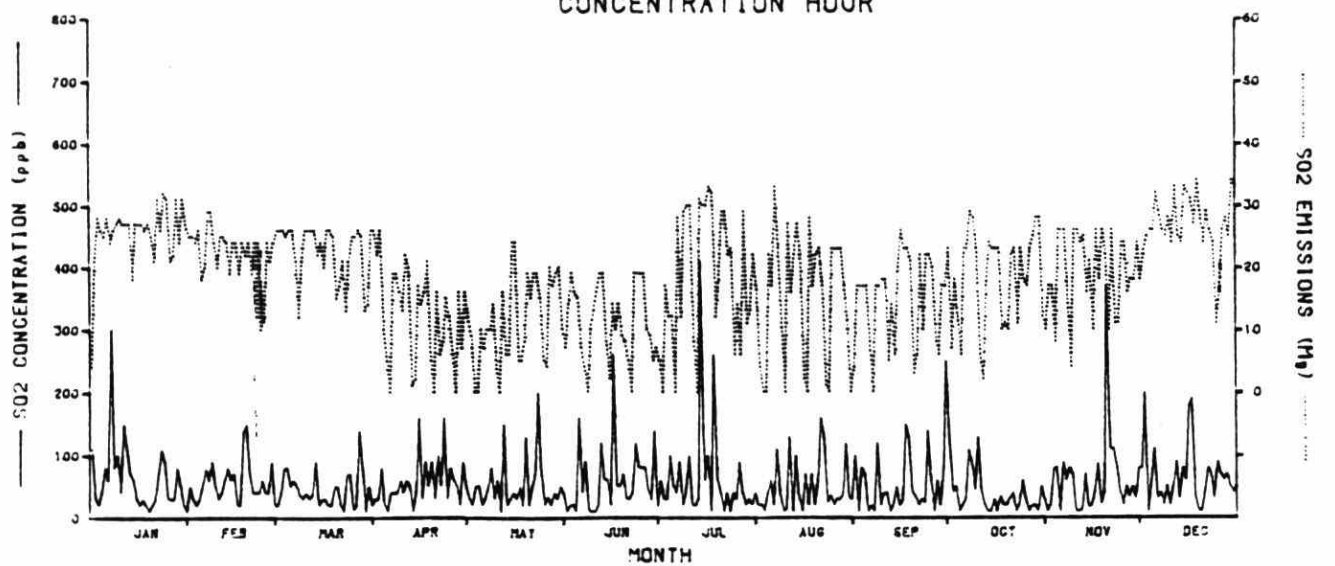
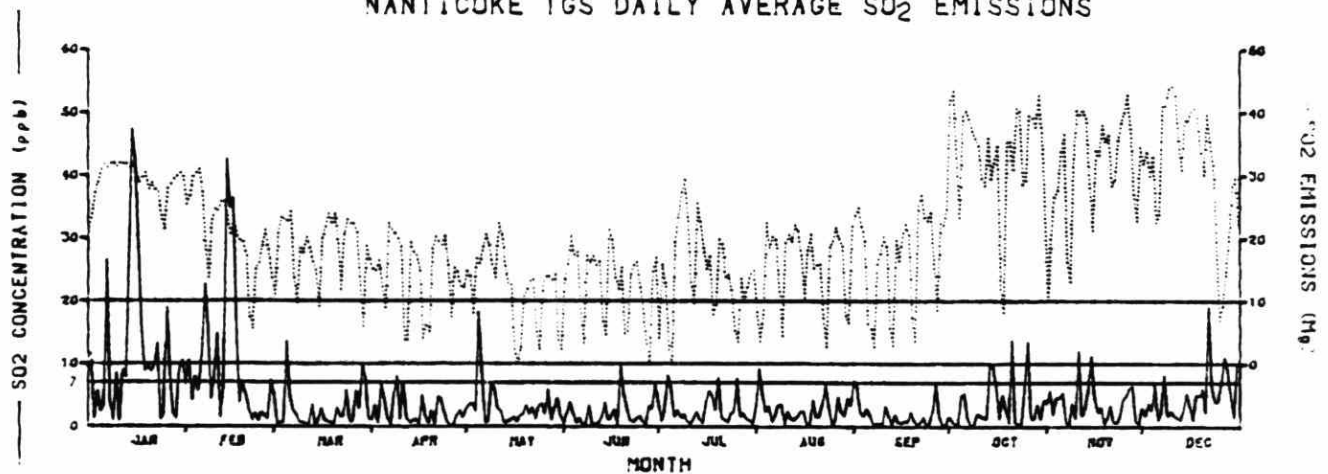
c) DAILY NETWORK MAXIMUM SO<sub>2</sub> CONCENTRATION AND NANTICOKE TGS SO<sub>2</sub> EMISSIONS AT THE MAXIMUM CONCENTRATION HOUR



Figure 51

DAILY STATISTICS FOR THE SO<sub>2</sub> NETWORK 1981a) DAILY NETWORK AVERAGE SO<sub>2</sub> CONCENTRATION AND NANTICOKE TGS DAILY AVERAGE SO<sub>2</sub> EMISSIONS

b) DAILY AVERAGE STATION LOAD AT NANTICOKE TGS AND DAILY AVERAGE AIR TEMPERATURE AT JARVIS MET TOWER

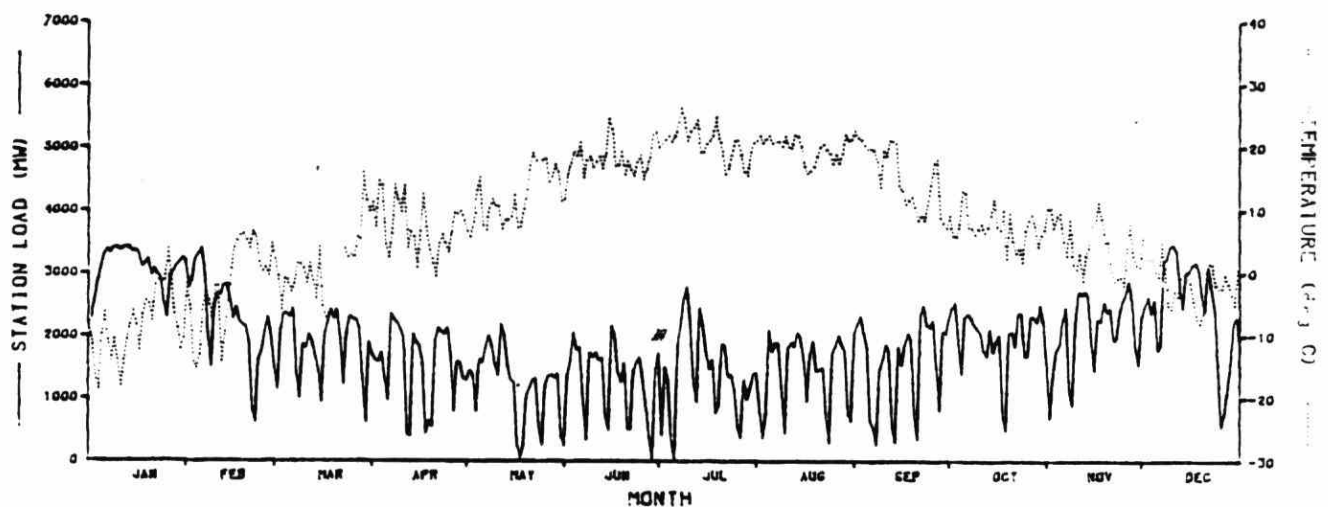
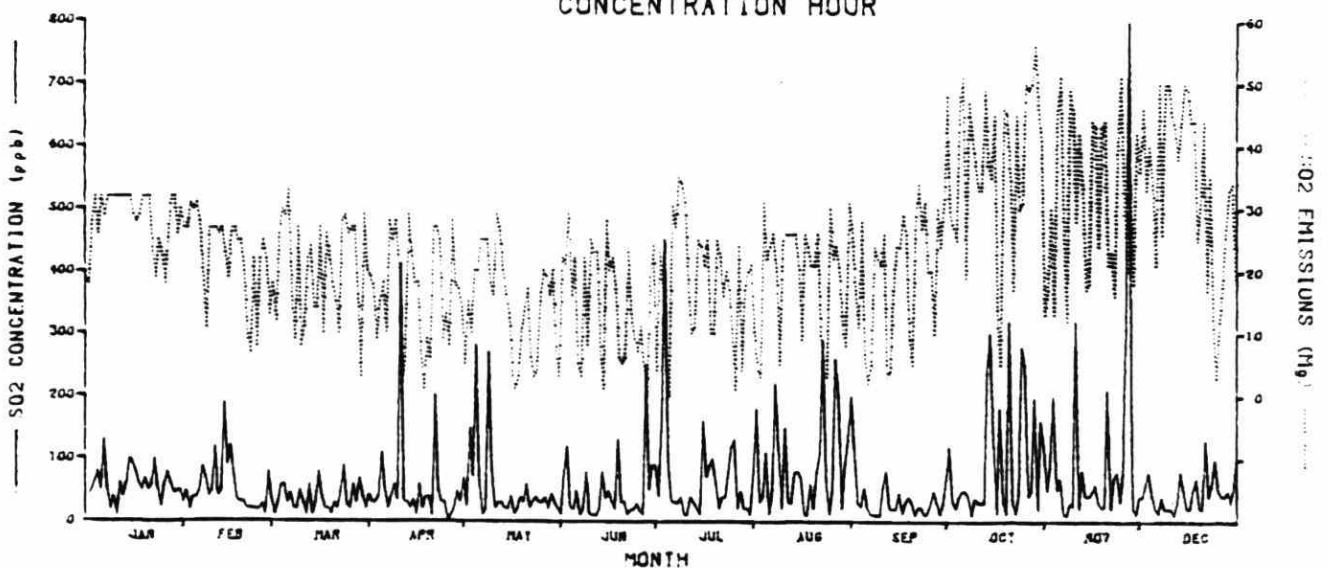
c) DAILY NETWORK MAXIMUM SO<sub>2</sub> CONCENTRATION AND NANTICOKE TGS SO<sub>2</sub> EMISSIONS AT THE MAXIMUM CONCENTRATION HOUR

Figure 52

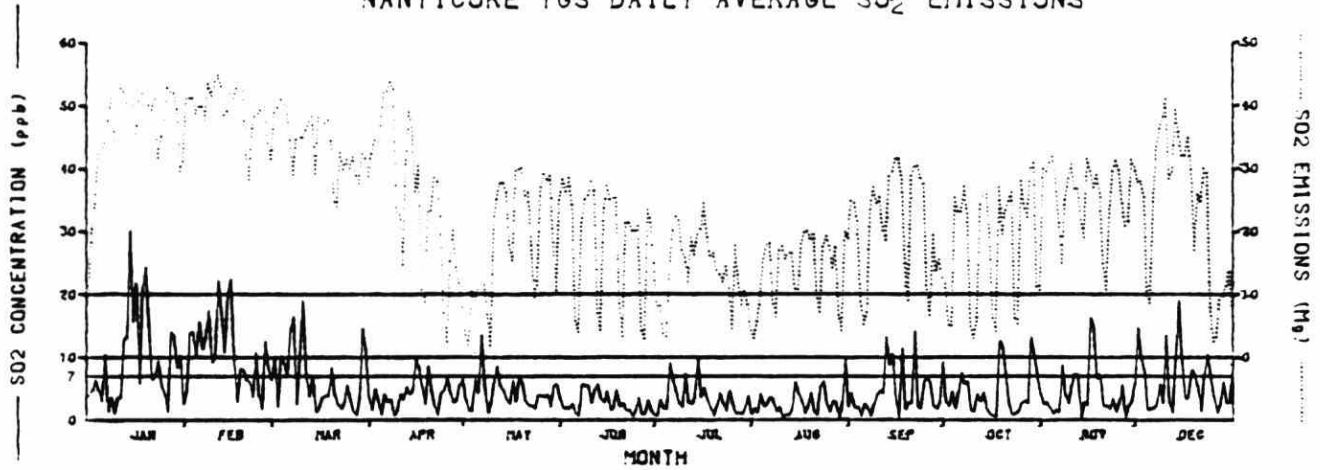
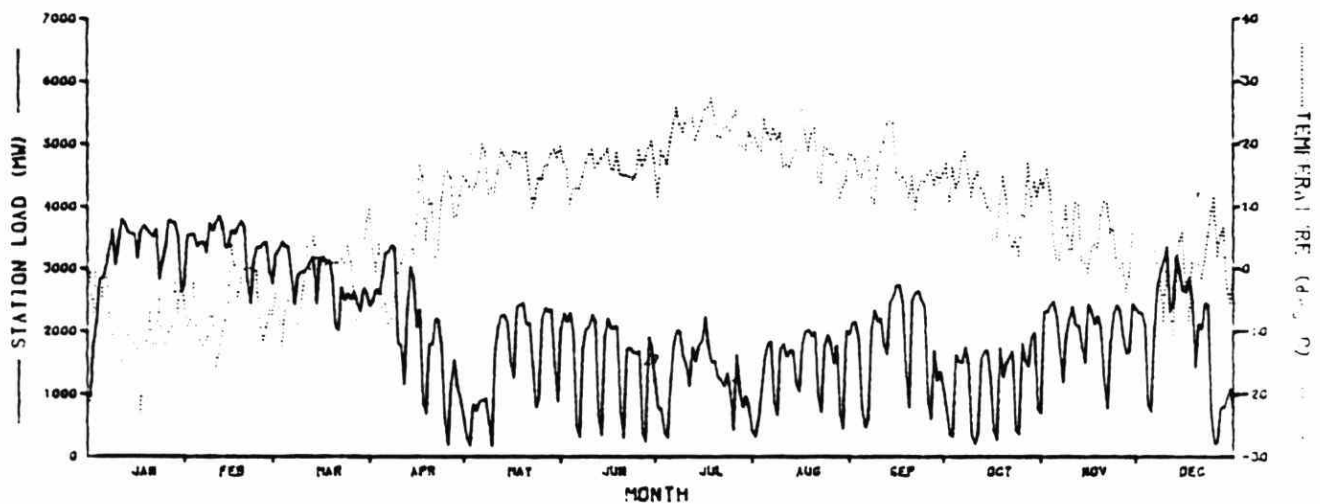
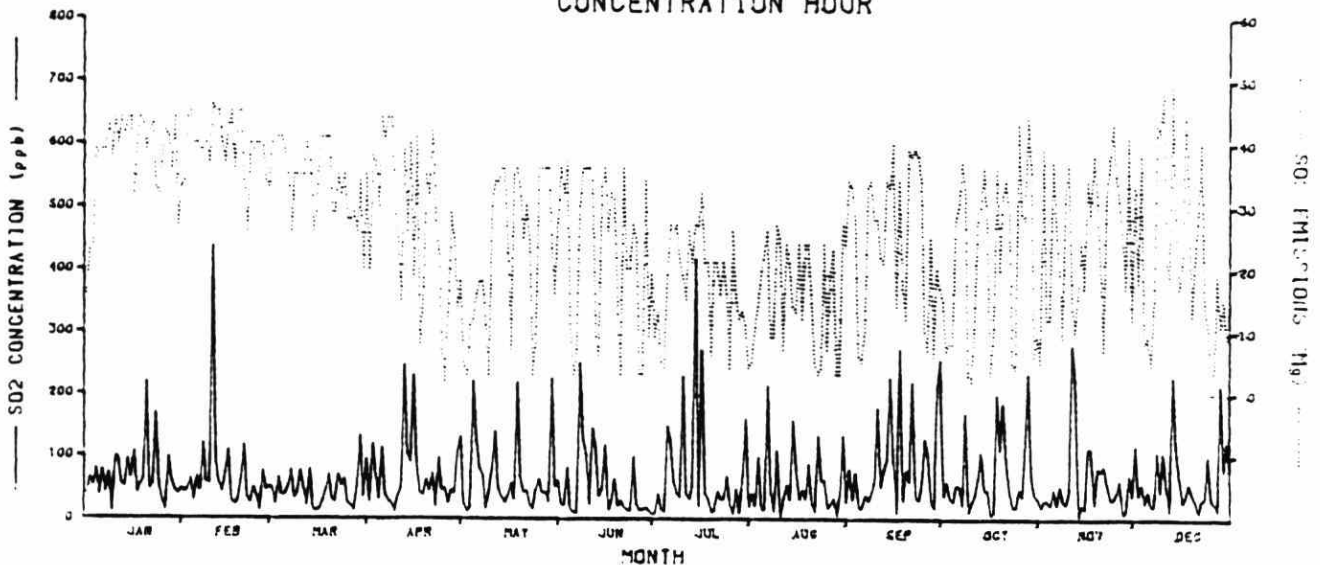
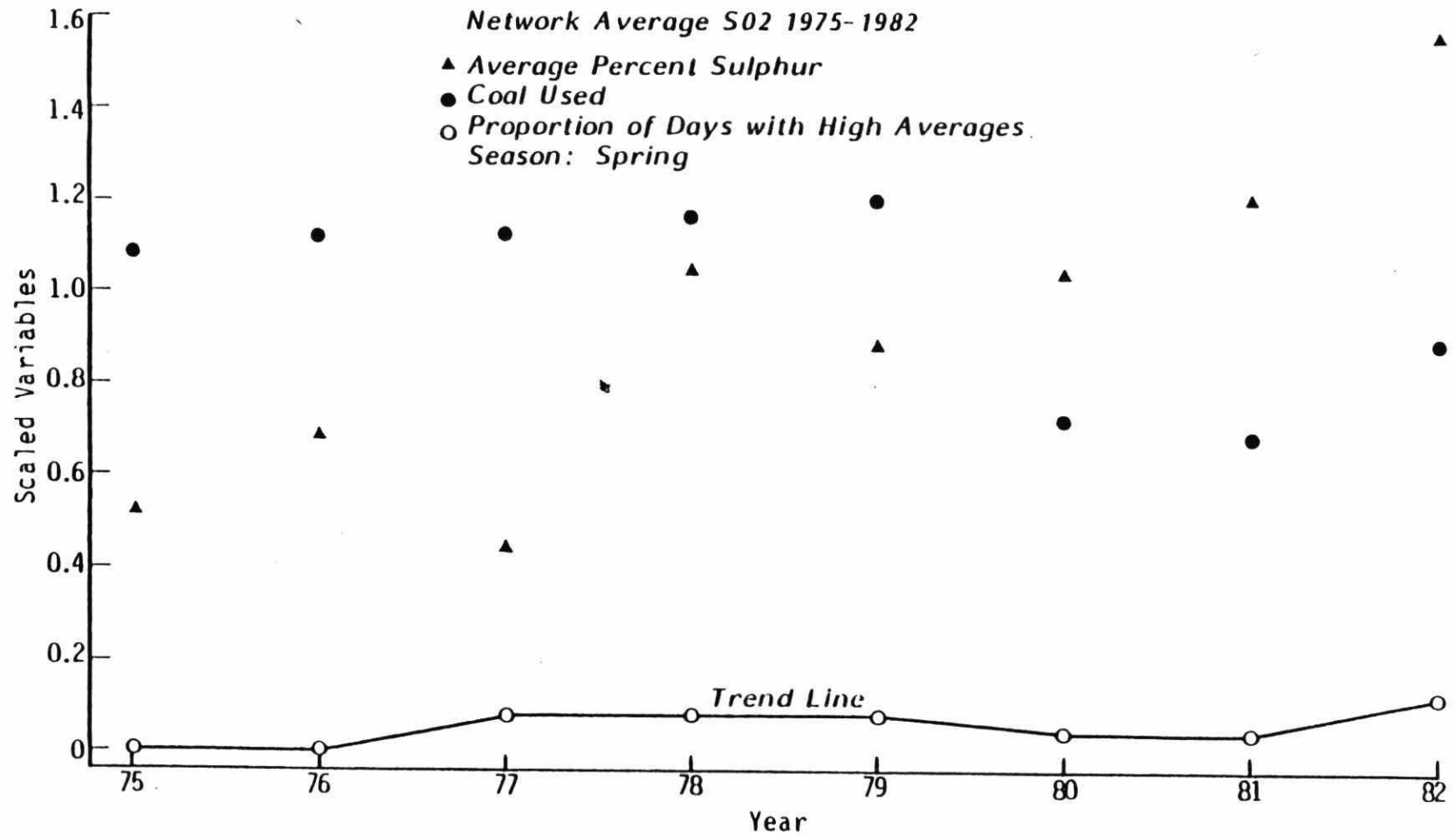
DAILY STATISTICS FOR THE SO<sub>2</sub> NETWORK 1982a) DAILY NETWORK AVERAGE SO<sub>2</sub> CONCENTRATION AND  
NANTICOKE TGS DAILY AVERAGE SO<sub>2</sub> EMISSIONSb) DAILY AVERAGE STATION LOAD AT NANTICOKE TGS AND DAILY  
AVERAGE AIR TEMPERATURE AT JARVIS MET TOWERc) DAILY NETWORK MAXIMUM SO<sub>2</sub> CONCENTRATION AND  
NANTICOKE TGS SO<sub>2</sub> EMISSIONS AT THE MAXIMUM  
CONCENTRATION HOUR



Figure 53



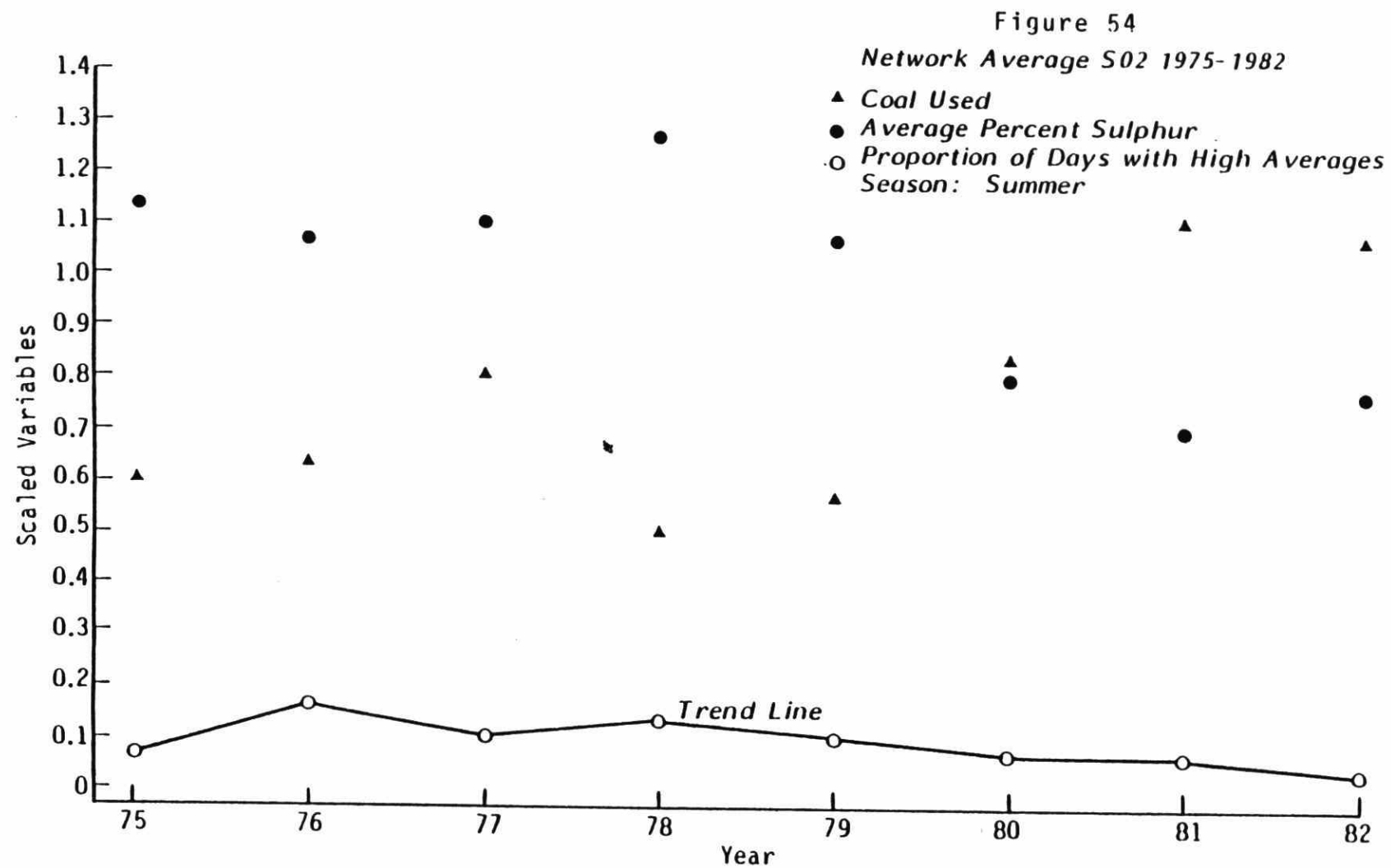
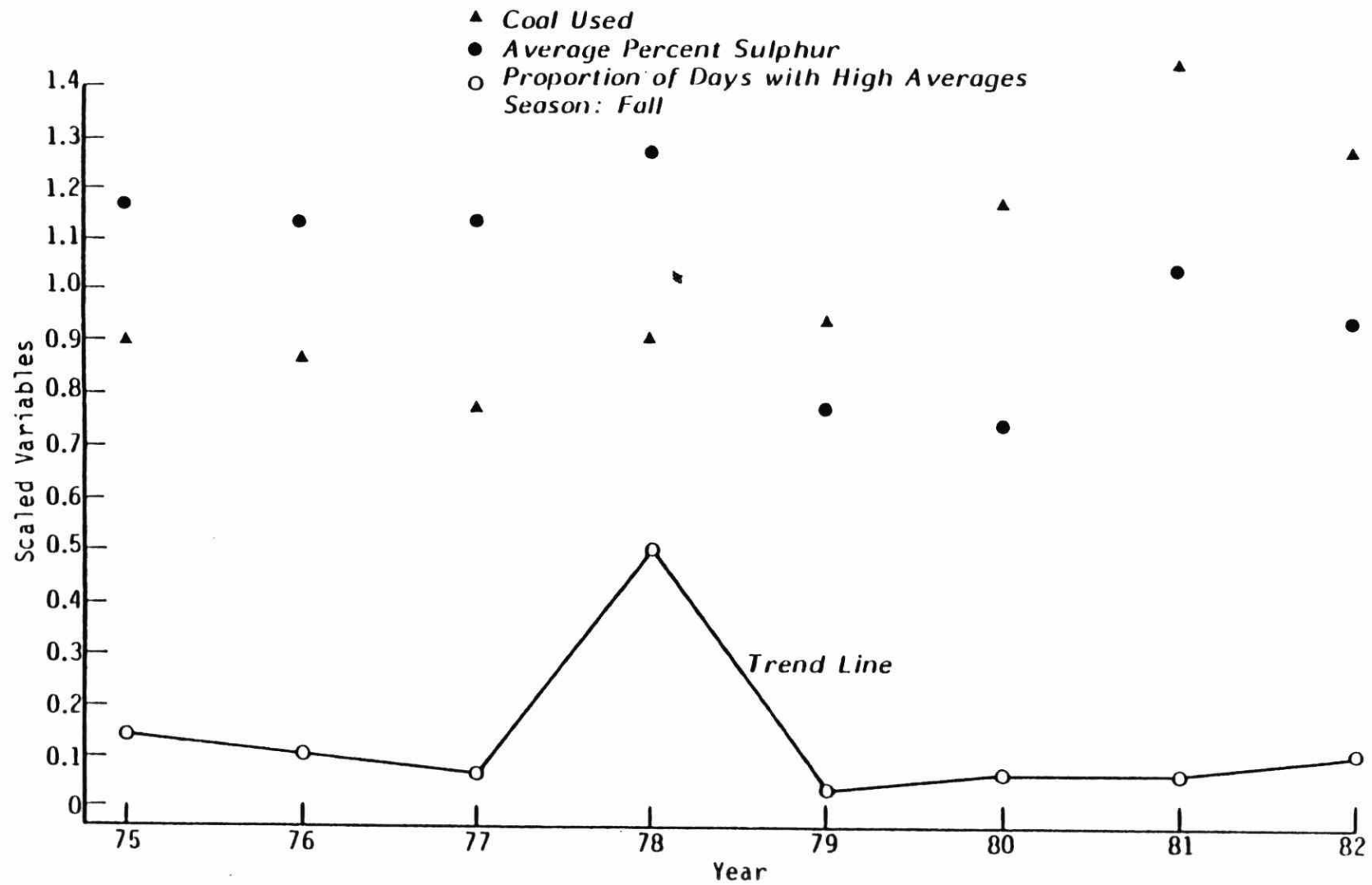


Figure 55  
Network Average SO<sub>2</sub> 1975-1982



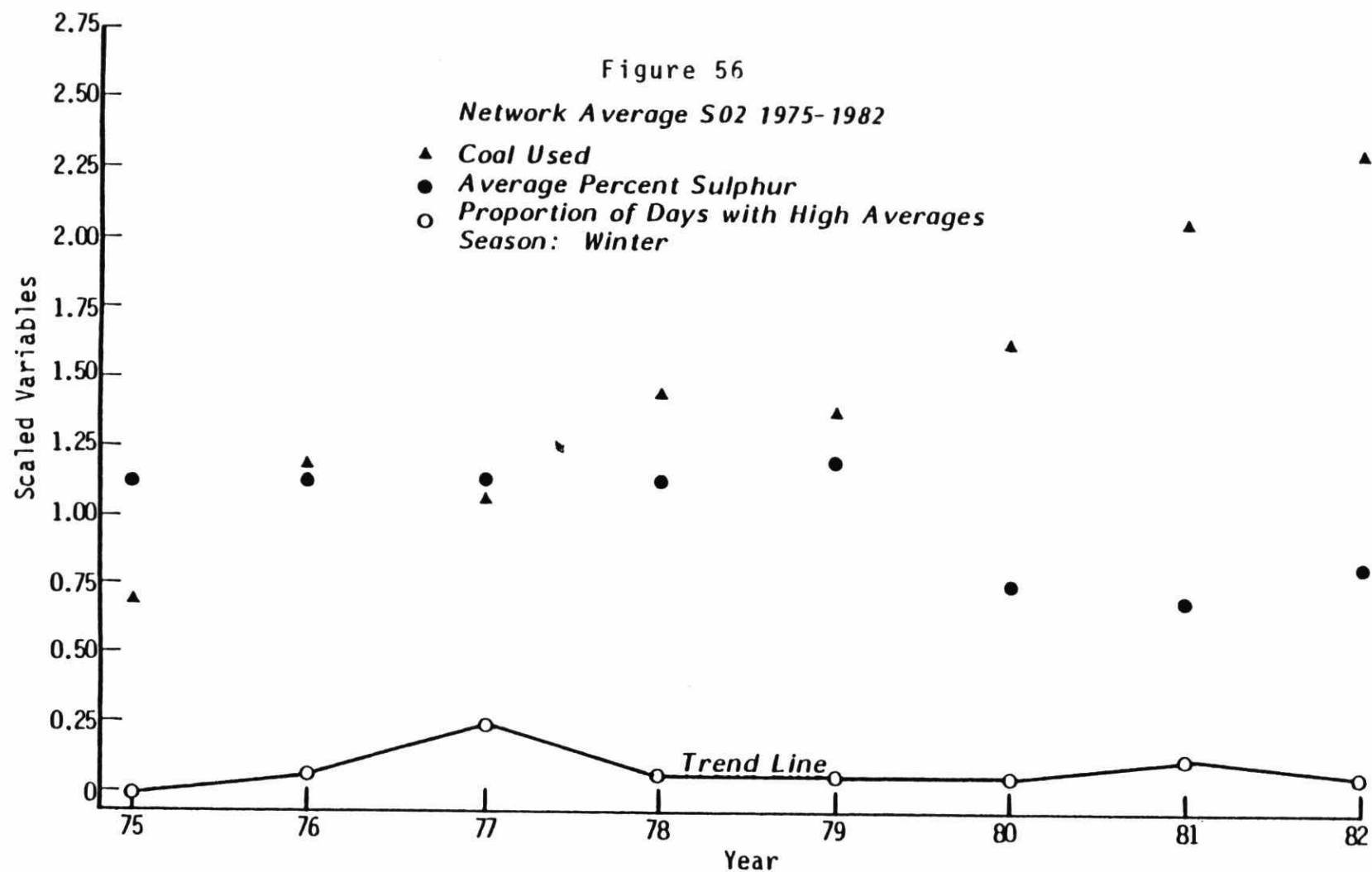
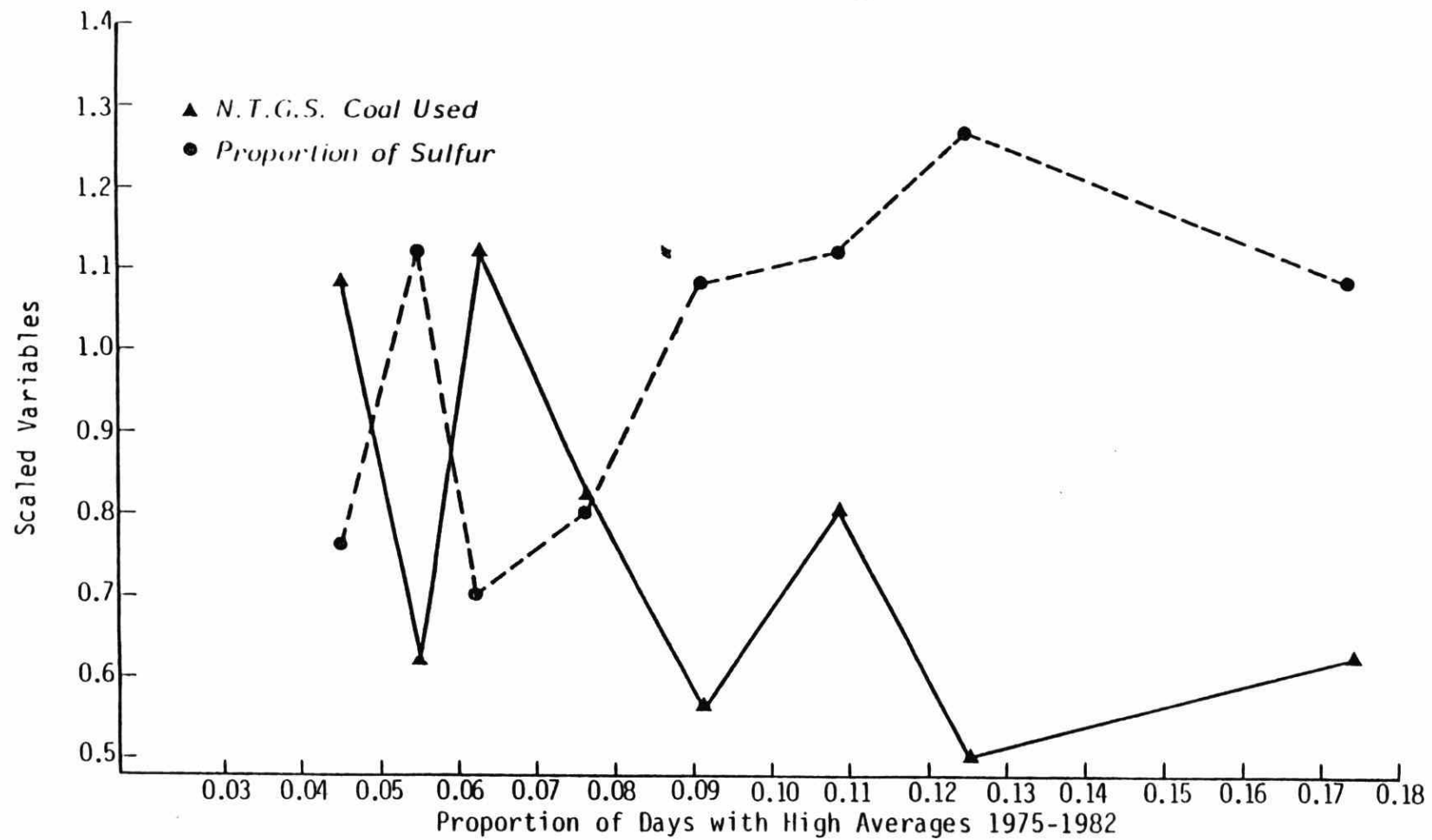


Figure 57

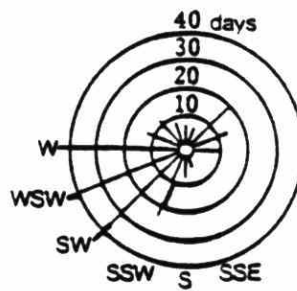
Amount of Coal Used and Proportion of Sulfur Plotted Against  
Proportion of Days With High  $\text{SO}_2$  Averages - Summer



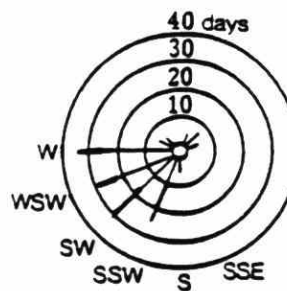
6-15 km/hr  
Winter

Too Few  
Cases

16-30 km/hr



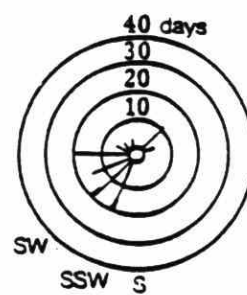
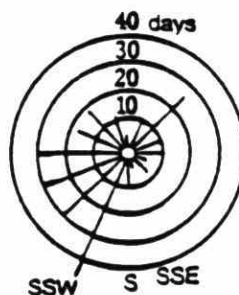
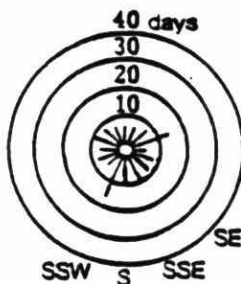
30 km/hr



Relative Impact  
by Wind Sector

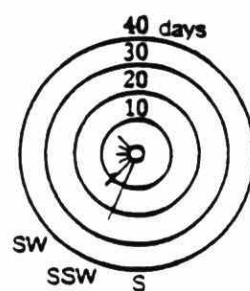
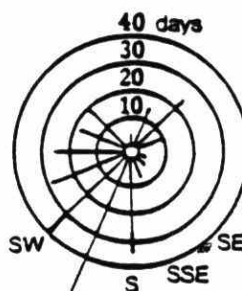
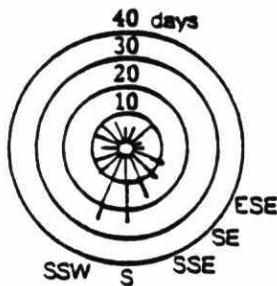
	Number of Days	Directions Marked	Others	Total
<120 ppb	175	150	325	
>=120 ppb	64	5	69	
Total	239	155	394	

Spring



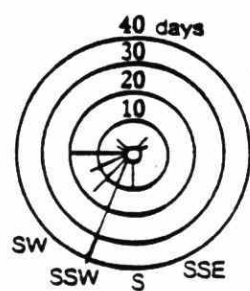
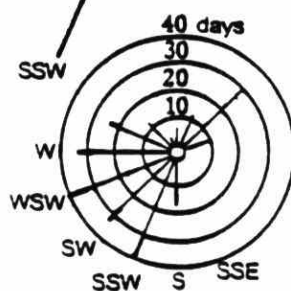
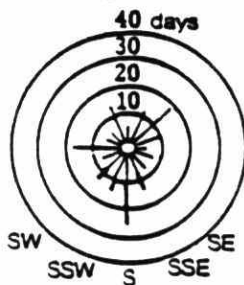
	Number of Days	Directions Marked	Others	Total
<120 ppb	114	332	446	
>=120 ppb	34	14	48	
Total	148	346	494	

Summer



	Number of Days	Directions Marked	Others	Total
<120 ppb	231	238	469	
>=120 ppb	91	5	96	
Total	322	243	565	

Fall



	Number of Days	Directions Marked	Others	Total
<120 ppb	231	250	481	
>=120 ppb	75	8	83	
Total	306	258	564	

- Number of days with maximum <120 ppb
- Number of days with maximum >=120 ppb

Figure 58

FREQUENCIES OF DAILY NETWORK MAXIMUM SO<sub>2</sub> BY SEASON  
WIND SPEED AND WIND DIRECTION

Figure 59

Network Daily Maxima S02 1976-1982

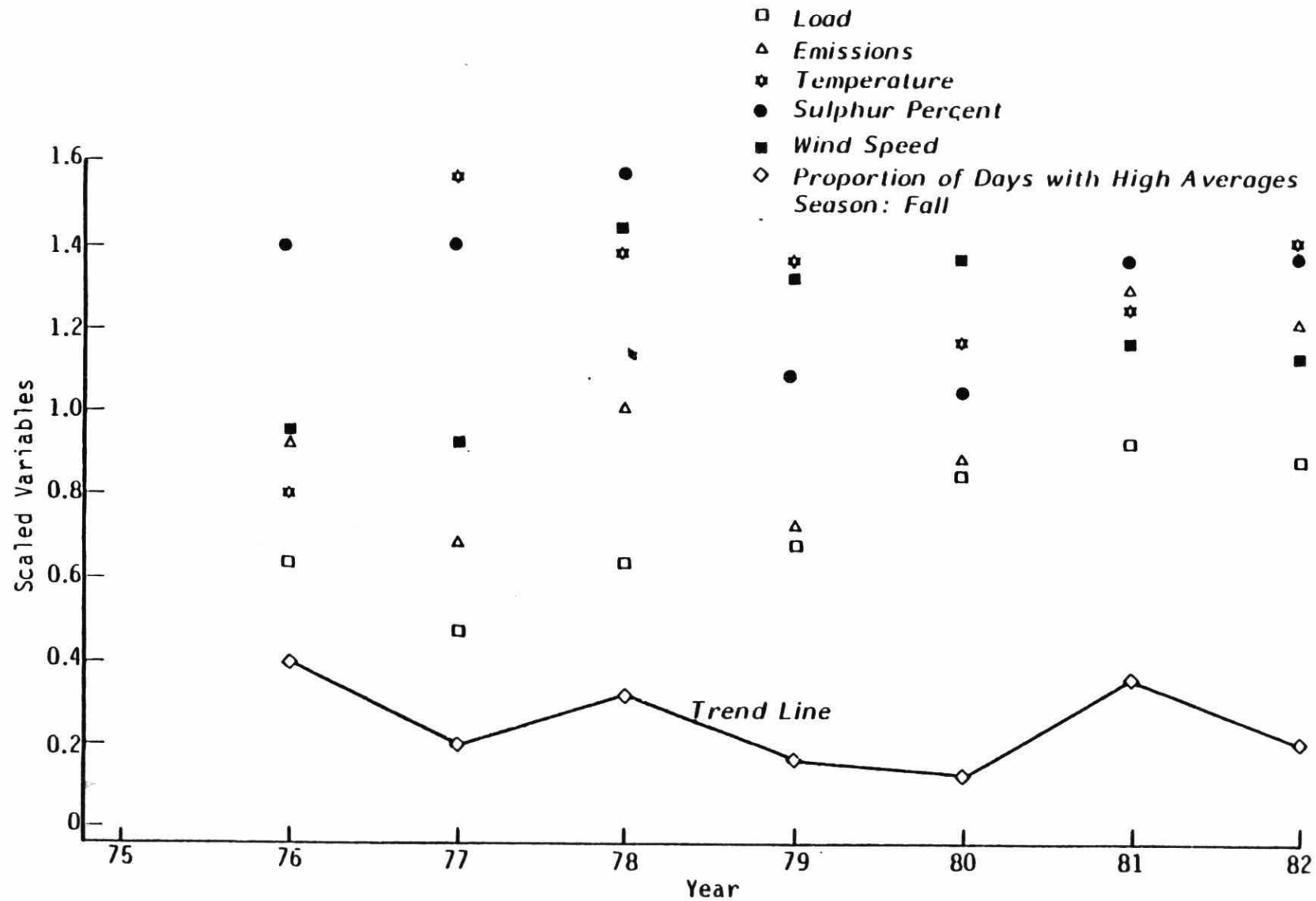


Figure 60

Network Daily Maximum SO<sub>2</sub> 1976-1982

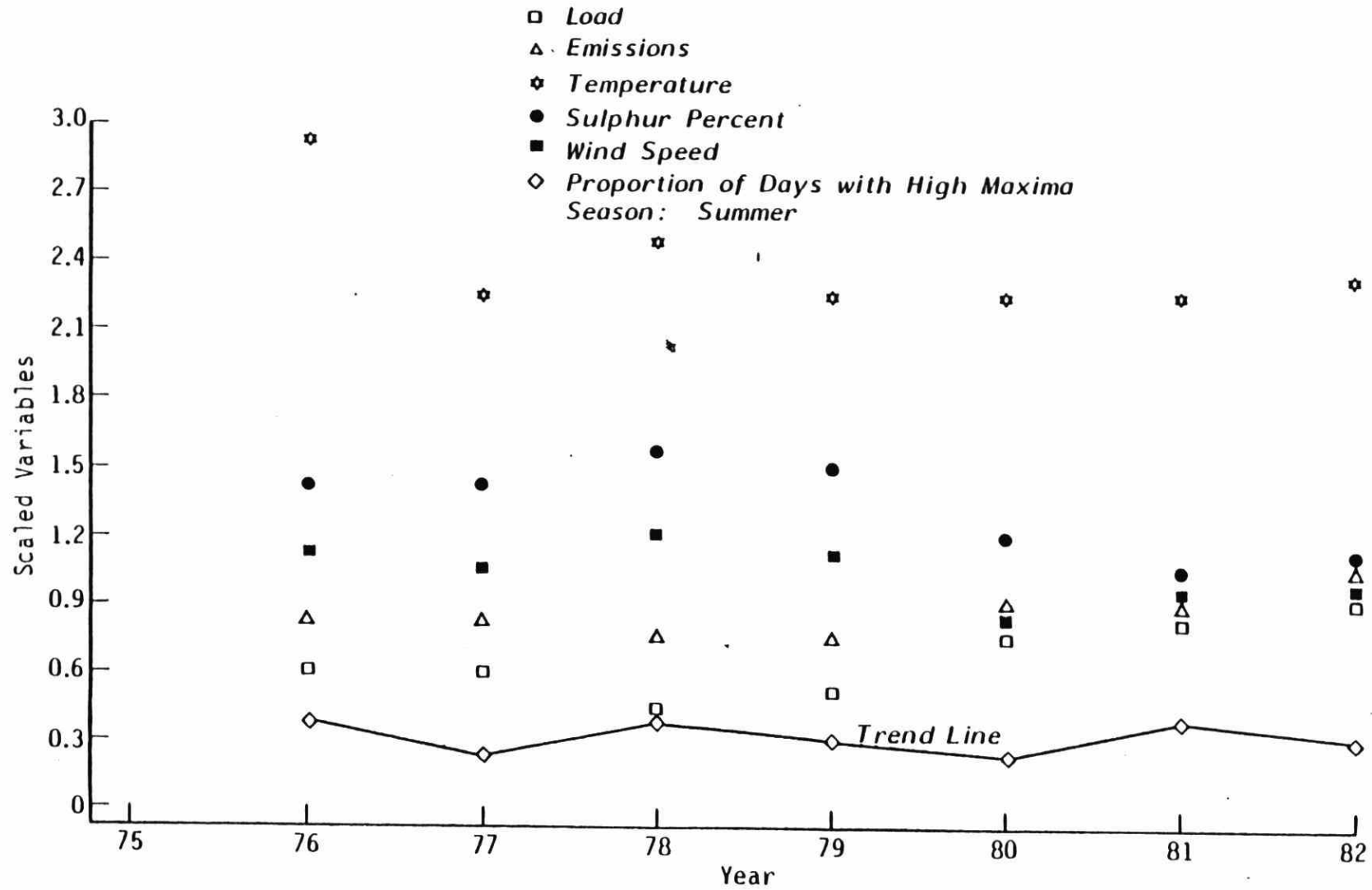




Figure 61

Network Daily Maximum S02 1975-1982

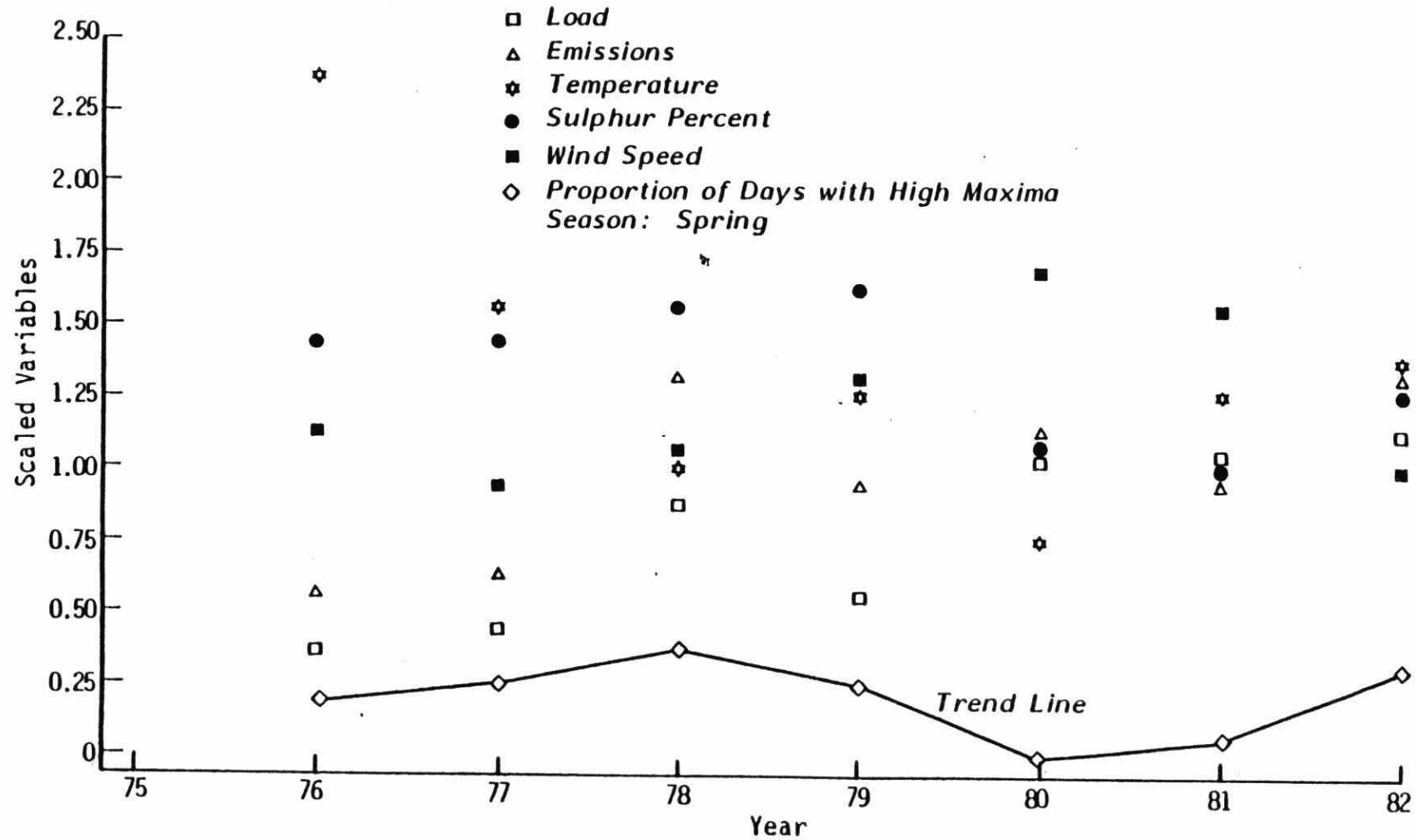


Figure 62  
 Network Daily Maximum S02 1977-1982

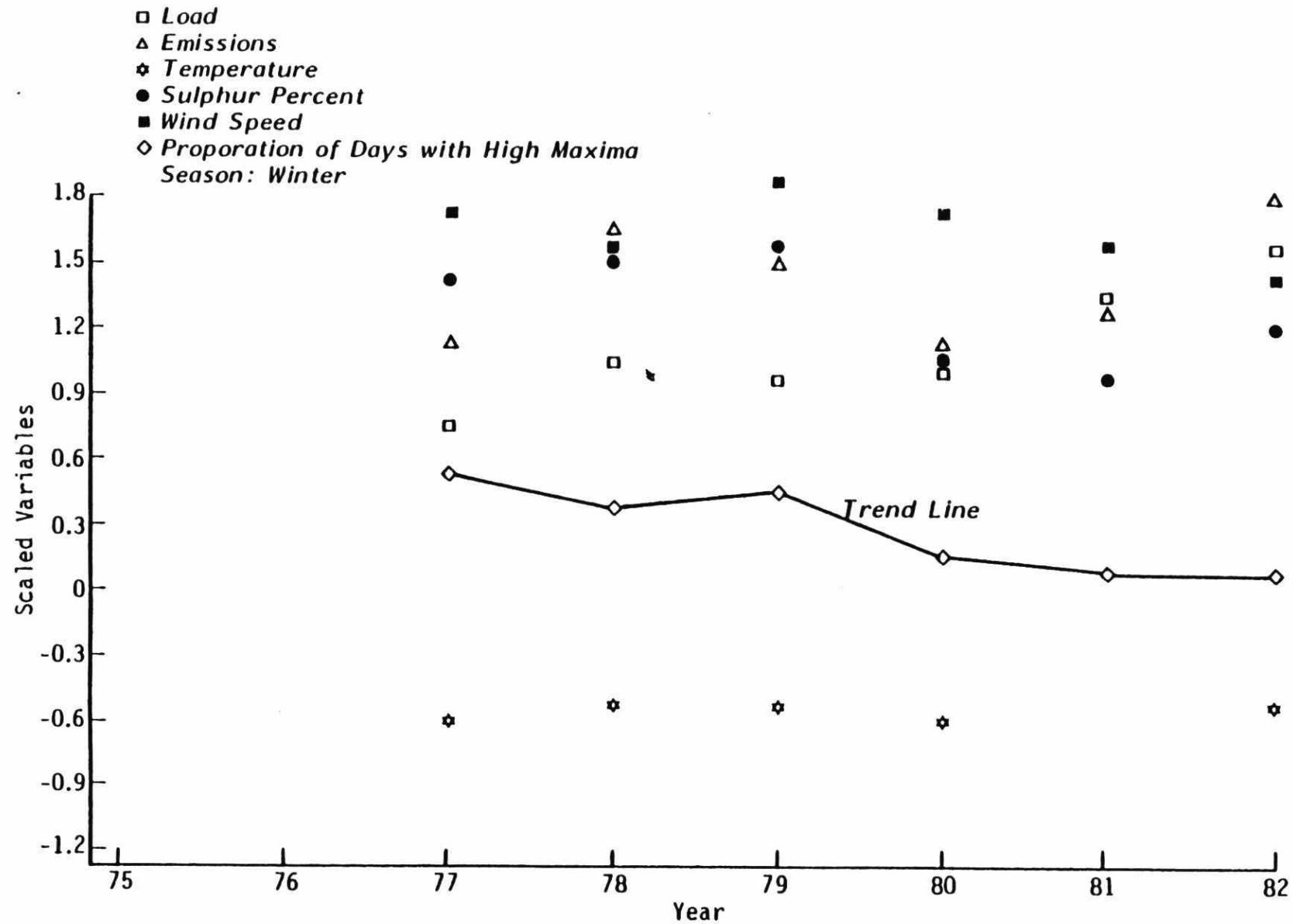


Figure 63

Wind Speed Plotted Against Proportion of Days  
With High Maxima - Spring

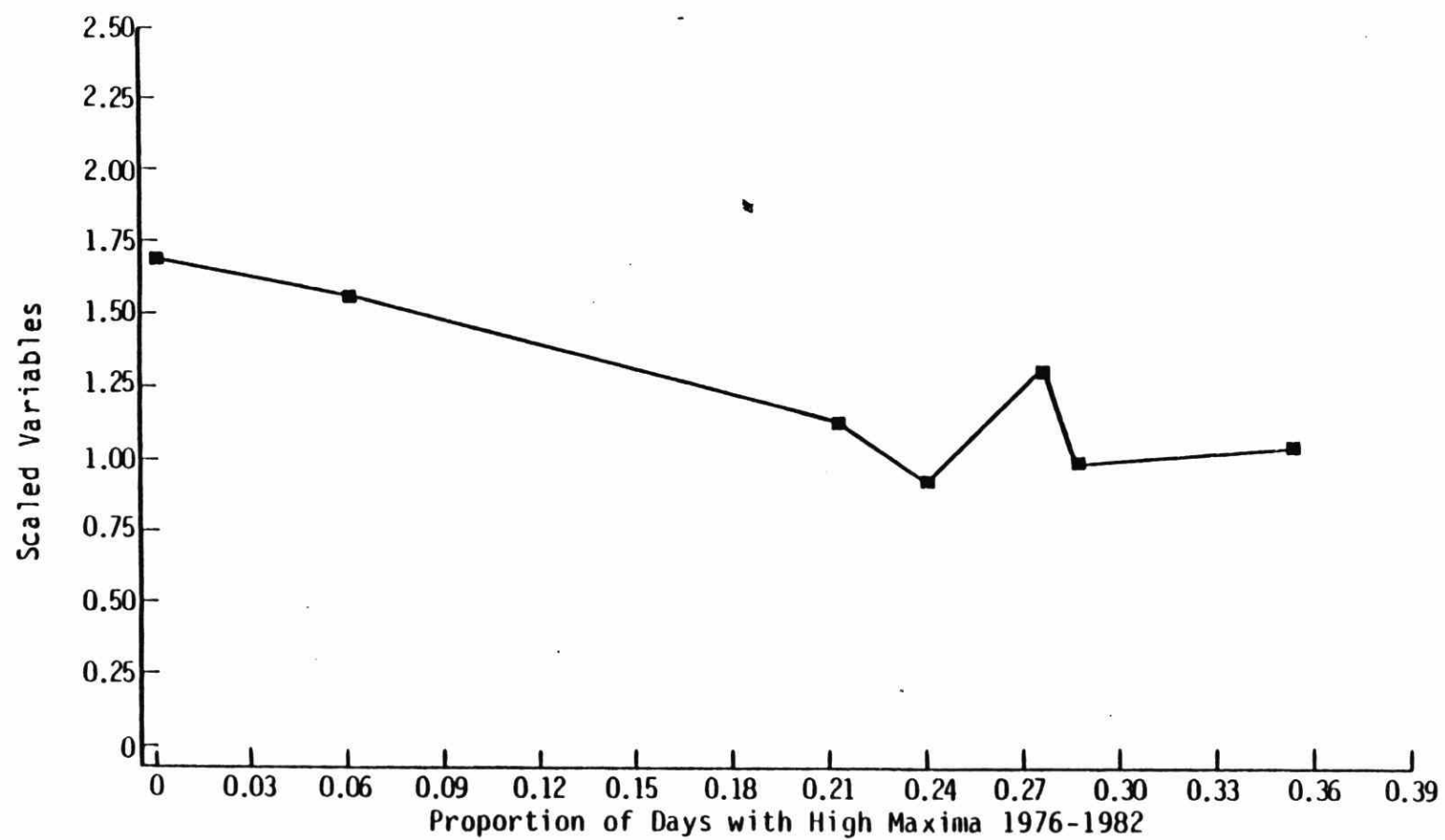


Figure 64

Percentage of Sulfur, Load and Emissions Plotted Against  
Proportion of Days With High Maxima - Winter

